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Vegetation Competition and Responses: Proceedings of the Third Annual Vegetation Management Workshop

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Vegetation Competition and Responses: Proceedings of the Third Annual Vegetation Management Workshop

February 15 – 17, 1988
Vancouver, B.C.

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FOREWORD

The workshop, Vegetation Competition and Responses, was held on February 15 – 17, 1988 in Vancouver, B.C. Over 150 people attended the workshop, which featured oral presentations, poster sessions and four special workshop sessions.

The objective of the workshop was to facilitate discussion of current research in vegetation management, with a focus on vegetation competition and responses. Discussion centered on investigations of the nature of competition and the processes important in predicting the response to treatments. In two of the special workshop sessions, participants considered environmental factors important in vegetation management research and the applications of plant growth analysis to vegetation management research. Another workshop, on plant population biology, provided a forum for discussion of how current information on the mode and success of plant establishment and plant growth rates be used to predict the response of vegetation to management treatments. The workshop on the physiology of crop trees focussed on the responses of seedlings to stress and implications for vegetation management. This proceedings includes summaries of the papers and posters that were presented as well as summaries of the special workshop sessions.

Special thanks are extended to the many people who contributed to the workshop. Kathy Banky was responsible for many of the logistical considerations. Phil Comeau, Craig DeLong, Peter Jolliffe, Denis Lavender and Alison Nicholson made up the organizing committee. Sessions were chaired by G. Wayne Coombs, Hamish Kimmins, George Krumlik and Dan Lousier. The four special workshop sessions were organized by Andy Black, Dave Brand, Stuart Childs, Dave DeYoe, Steve Grossnickle, Chris Hawkins, Denis Lavender, Roberta Parish and Dave Spittlehouse.

Funding for the workshop and the proceedings was provided, in part, by the Canada-British Columbia Forest Resource Development Agreement (FRDA). The Research Branch of the B.C. Ministry of Forests and Lands and the Department of Forest Sciences at the University of British Columbia also contributed to the workshop.

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TABLE OF CONTENTS

FOREWORD iii

PAPERS

VEGETATION COMPETITION AND RESPONSES: EXPERIMENTAL RESULTS

Downslope Movement and Efficacy of Hexazinone in the Sub-Boreal Spruce Zone
Pierre Beaudry 2

Carbon Allocation, Morphology and Physiology of Douglas-fir (*Pseudotsuga menziesii* Mirb. Franco) and Red Alder (*Alnus rubra* Bong.) Saplings in Response to Light and Soil Moisture Availability
S.S. Chan, S.R. Radosevich, and J.D. Walstad 3

Light Attenuation by Thimbleberry-fireweed Communities in the ICH Zone and its Potential Effects on Conifer Growth
Phil Comeau 5

Changes in Structure of Three Vegetation Complexes over the Growing Season and Their Effect on Competition for Light with Hybrid Spruce
Craig DeLong 8

Duration and Intensity of Vegetation Control: Establishing Seedling Growth Potential
D.R. DeYoe and B.G. Dunsworth 10

Initial Vegetation Development following Clearcutting and Slashburning in the Coastal Western Hemlock Zone of B.C.
M.C. Feller 11

The Relationship of Carbohydrate Content of Plants to Their Ability to Sprout After Mechanical Treatment
Stephen D. Hobbs and Michael S. Crawford 15

Chemical and Manual Control of Thimbleberry (*Rubus parviflorus*): A Rate and Timing Trial
P. LePage and J. Pollack 17

Response of Vegetation to Mechanical Site Preparation Treatments in North Central British Columbia
Andy MacKinnon and Bob McMinn 19

A Test of the "Resource pre-emption" and "Resource depletion" Models of Plant Competition in Mixtures of *Pinus ponderosa* and *Calamagrostis rubescens*
Terry D. Peterson 24

Forest Vegetation Management on Coastal Alluvial Sites: The Skeena and Kitimat Valley Experiments
J. Pollack and P. LePage 25

Douglas-fir and Red Alder Competition in Mixed and Monoculture Stands
L.J. Shainsky and S.R. Radosevich 26

Impact of Competing Vegetation on Site Water Balance
D.L. Spittlehouse 28

Response of Vegetation to Herbicides in the Nelson Forest Region
C.F. Thompson 31

Interspecific Competition Indices for Vegetation Management Decisions in Young Douglas-fir Stands
Robert G. Wagner and Steven R. Radosevich 33

Effects of Vegetation and Soil Profile on Planted White Spruce Seedlings
Tricia L. Wurtz and John Zasada 35

POSTERS

VEGETATION COMPETITION AND RESPONSES: EXPERIMENTAL RESULTS

The Impact of Non-coniferous Vegetation on the Performance of Engelmann Spruce (*Picea engelmannii* Parry) Seedlings on Subalpine Forest Cutovers in Southern B.C.
C.L. Caza and J.P. Kimmins 38

Effects of Shrubs and Herbs on Conifer Regeneration and Microclimate in the *Rhododendron-Vaccinium-Menziesia* Community of South-Central British Columbia
K. Dave Coates 41

Germination, Survival and Early Growth of Red Alder Seedlings in the Central Coast Range of Oregon
Sybille Haeussler and J. C. Tappeiner II 43

Response of Vegetation to Burning in the Sub-Boreal Spruce Zone
Evelyn H. Hamilton and H. Karen Yearsley 45

An Evaluation of the Clearing Saw for Brushing Shrub Dominated Plantations in the ICH
Sylvi D. Holmsen R.P.F. and Roger J. Whitehead 49

An Overview of Vegetation Problems in the ICHm2 and ICHb Subzones of the Southern Interior
Jean Mather 50

Root Distribution and Biomass of Competing Vegetation on Two Recently Burned Sites in the CWHb Subzone
C. Messier, R. Oran and J.P. Kimmins 51

Increasing Seedling Growth on Salal Sites Using Controlled-release Fertilizer
K.L. Nuszdorfer and F.C. Nuszdorfer 54

Competition Between Sitka Alder and Lodgepole Pine in the Montane Spruce Zone
Suzanne Simard 56

The Effect of Glyphosate Treatments on a Mixed Brush Community in the ICHd Subzone (SX 83407)
C.F. Thompson 57

Ecology and Management of Broadleaved Species in the Oregon Coast Range
John C. Zasada, John C. Tappeiner, Peter Ryan and Bruce Maxwell 61

WORKSHOPS

COMPETITION AND RESPONSES: ENVIRONMENTAL FACTORS, SEEDLING PHYSIOLOGY, GROWTH ANALYSIS, AND POPULATION BIOLOGY

Environmental Factors Important in Vegetation Competition Studies
D.L. Spittlehouse 64

Physiology of Crop Trees: Response and Tolerance of Environmental Stress and Implications for Vegetation Management
Dave R. DeYoe 66

Conifer Seedling Establishment on Reforestation Sites: Environmental Influences and Ecophysiological Responses
S. Grossnickle 70

Plant Growth Analysis: Application to Vegetation Management Research
P.A. Jolliffe, D.G. Brand, and C.D.B. Hawkins 72

Bud Bank, Seed Bank, Seed Rain and Forest Succession in the Coastal Western Hemlock Zone of Southwestern B.C.
Ann B. McGee 76

Reproductive Biology of Trees and Shrubs in Interior Alaska
John C. Zasada 78

A Population Modeling Approach to Vegetation Management Research with Reference to *Rubus spectabilis* and *R. parviflorus*
Bruce Maxwell and Steve Radosevich 80

OTHER CONSIDERATIONS

A Technique for Measuring Light Interception Through Conifer Canopies
Paul Alaback 82

Integrated Use of Field Survey Data: A Pilot System
David G. Brand 84

Prediction of the Rotation-length Consequences of Alternative Vegetation Management Strategies for Timber Yields, the Stand-level Economic Performance of Management, Soil Fertility and Site Productivity using the Ecosystem-level Forest Management Model FORCYTE-11
J.P. Kimmins and K.A. Scoullar 85

PAPERS

VEGETATION COMPETITION AND RESPONSES: EXPERIMENTAL RESULTS

Downslope Movement and Efficacy of Hexazinone in the Sub-Boreal Spruce Zone

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Incidents of downslope movement of hexazinone in the Prince Rupert Forest Region in 1985 and 1986 underscored the need for further trials to understand how hexazinone moves, and to fine-tune the existing application guidelines.

Hexazinone is designed to be applied directly to the soil surface by a spotgun or broadcast spray. Hexazinone is water soluble and soil mobile so that it is transported by soil water to the roots of the target species. Performance increases on moist soils but, if the site is continuously wet, off-site movement can occur. Familiarity with site specific environmental conditions such as soil moisture, soil temperature, rainfall and snowmelt regimes as well as soil texture and organic matter content, is important to achieve maximum benefit from hexazinone and minimize risks to non-target species.

A study, located in the Sub-Boreal Spruce Zone near Smithers, investigates the environmental and site processes that induce off-site movement and determines efficacy and crop tree tolerance. Two replications of twelve treatments combine three rates and two time periods of application on two soil types.

Hexazinone in the liquid formulation (Velpar L®) was applied at three rates: 2 ml/spot at 1 m X 1 m spacing; 4 ml/spot at 1.5 m X 1.5 m spacing; and, 6 ml/spot at 2 m X 2 m spacing. Twelve plots were treated in late May and twelve plots in early October 1987. These two application periods test the effects of two very different soil climate conditions on efficacy and downslope movement. During spring, soils are generally warm and moist, becoming warmer and drier as the season progesses into summer. However, during fall soils are cool and wet generally freezing shortly after chemical application causing a slowing down of hexazinone biodegradation. Come spring, the soils will be submitted to spring snowmelt, and subsequent saturation and extensive surface and subsurface runoff. Study of the fate of hexazinone under these two application regimes will help define the time periods that are acceptable for Velpar L® application in the SBS Zone.

To evaluate the influence of soil organic matter on the fate of hexazinone, two different soil types were tested. At the site near Moricetown (SBSe/06) the average surface organic layer is 8-10 cm, whereas at the site near Houston (SBSd/01), the soil is drier with an average organic layer of 1-2 cm.

Preliminary observations of permanently staked sample plots suggest that efficacy is improved in moist soils. All treatments on the drier site showed poor efficacy until the onset of rain, whereas on the moist SBSe site, acceptable vegetation control was achieved soon after treatment. Vegetation control was best on the closely spaced (1 m X 1 m) treatments on both soil types.

Downslope movement of hexazinone is measured for each experimental plot by collecting surface and subsurface soil water and assessing chemical damage to vegetation at fixed distances downslope (7, 12 and 25 m).

Preliminary results of chemical analysis of 50 of these water samples indicate that hexazinone moved predominantly as shallow subsurface interflow and that downslope movement was generally confined to 7-10 m. Vegetation assessments on the spring plots showed downslope damage greater than 10 m on only one plot. Because soil water flows most abundantly in the late fall and early spring, damage from downslope movement, if it occurred, will be more apparent in the 1988 growing season.

Information from continuous environmental monitoring (air and soil temperature, rainfall and snowmelt, soil moisture, solar radiation), from water sampling and from vegetation measurements will be analyzed over this winter. The site will continue to be monitored through 1988 and 1989, and the collected information included in the analysis. This long term information is needed because of the residual nature of hexazinone. From this study will come information to help determine the environmental fate of hexazinone in the SBS Zone, understand factors effecting its movement and predict its behaviour on other sites.

Carbon Allocation, Morphology and Physiology of Douglas-fir(*Pseudotsuga menziesii* Mirb. Franco) and Red Alder (*Alnus rubra* Bong.) Saplings in Response to Light and Soil Moisture Availability

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Light and soil moisture levels simulating the environmental conditions that are commonly present on a site, following a disturbance in the coastal forests of the Pacific Northwest, were imposed upon 1- to 4-year-old Douglas-fir and red alder trees.

The objectives of this study were to:

1. examine and compare the relationships between Douglas-fir and red alder morphology, carbon allocation and physiology, in response to light and soil moisture availability; and
2. develop allometric predictors of stress responses to limitations in environmental resources.

Results from this study indicate that Douglas-fir and red alder have different sensitivity (as expressed by growth), to light and water availability. Differences in plant growth were explained in terms of morphology, unit leaf area photosynthetic rates, stomatal conductance, water use efficiency, plant water potential, soil moisture depletion, leaf area growth and carbon allocation.

Individual 1-year-old transplants of both species were grown for three years in the field at two levels of light (normal sunlight versus 15% normal) and two levels of soil moisture (irrigated versus non-irrigated) in all four possible combinations. Light was regulated with shade tents and soil moisture was maintained by drip irrigation. Height, stem diameter, cover, carbon allocation (foliage, stem, branches, buds and roots), photosynthetic rates, leaf conductance, xylem water potential and soil moisture depletion were measured for a three-year period after transplanting.

Low light levels reduced the stem diameter, crown cover and height growth of red alder and the stem diameter growth of Douglas-fir. Low soil moisture decreased the stem diameter, crown cover and height growth of red alder, but responses were not apparent in Douglas-fir. Height growth of Douglas-fir was not affected by the different levels of light and soil moisture.

Red alder maintained higher unit leaf area photosynthetic and leaf conductance values than Douglas-fir. The peak mid-morning photosynthetic rates and leaf conductances correlated with stem diameter growth and were sensitive indicators of the light and water environment. Photosynthesis and leaf conductances for each species were reduced in the mid-afternoon on warm-dry summer days. Values were generally more depressed for Douglas-fir than red alder. High vapor-pressure deficit, resulting from low humidity, coupled with warm temperatures, depressed photosynthesis and conductance even with soil moisture at field capacity. Red alder depleted soil moisture (lowered soil water potential) throughout a larger volume than Douglas-fir.

The growth of red alder is more adversely affected by low soil moisture than is Douglas-fir. Low soil moisture availability reduced red alder leaf area and leaf weight by almost two-thirds and increased the allocation of biomass to roots versus shoots. Red alder trees growing under low light conditions had 33-50% of the leaf area and between 10-20% of the biomass of trees growing in full light. However, low light levels did not alter the shoot:root allocation patterns as did low soil moisture availability. Low light levels decreased Douglas-fir growth by up to 67% and resulted in a higher allocation to shoots versus roots.

Allocation patterns and priorities in red alder are primarily driven by soil moisture availability, whereas light availability is the primary mechanism driving Douglas-fir allocation. These trends in morphology, physiology and carbon allocation suggest that differences in growth and survival strategies are strongly mediated by resource availability. The patterns of sensitivity and responses of Douglas-fir and red alder to the light and water environment also suggest potential opportunities to manipulate the resource

environment to achieve management goals. The success and prevalence of red alder on riparian sites is driven by soil moisture availability. High survival and rapid growth of Douglas-fir on south aspects in the coast range is strongly driven by the higher intensity and duration of available light. Thus, management of mixed red alder and Douglas-fir stands requires a situation where adequate water is available for red alder growth and light is available to sustain maximum Douglas-fir growth.

Light Attenuation by Thimbleberry-fireweed Communities in the ICH Zone and its Potential Effects on Conifer Growth

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INTRODUCTION

In cool, moist areas of the southern interior of B.C., dense canopies of non-crop vegetation may develop following harvesting, competing with conifer seedlings for light. Thimbleberry (*Rubus parviflorus* Nutt.) and fireweed (*Epilobium angustifolium* L.) occur as dominant species in early seral communities on many sites in the Interior Cedar Hemlock (ICH) Zone of southern B.C. On moist (hygric) rich sites, thimbleberry may develop dense cover, dominating early seral communities. Dense patches of fireweed may occur on some mesic and subhygric sites following fire. This summary presents preliminary results from a study of competition for light in thimbleberry-fireweed communities in the ICHa subzone near Nelson, B.C. The project was funded under the cost-shared component of the 5-year (1985-1990) Canada-British Columbia Forest Resource Development Agreement (FRDA), project 3.48.

METHODS

Data were collected from 40 1 m X 1 m plots during mid to late July of 1987. In each plot, percent cover and height of each species were recorded and photosynthetic photon flux density (PPFD; 400 - 700 nm) was simultaneously measured above the canopy using a quantum sensor (LI-190), and at ground level using a line quantum sensor (LI-191) attached to a datalogger (LI-COR LI-1000). All vegetation exceeding 4 cm height was subsequently clipped from each plot, separated into leaf and shoot material by species, oven-dried at 70 C for 72 hours, and weighed. From each plot, 5-to-10 fresh leaves of each species were collected, pressed, and dried. The projected area of these leaves was measured using a LI-COR leaf area meter. For each species the ratio of surface area to weight was used to convert leaf dry weight to a leaf area index.

RESULTS AND DISCUSSION

The leaf area index (LAI) of measured plots ranged from 0.5 to 10.1 m^2 m^{-2} and the sum of species cover ranged from 20% to 143%. The maximum LAI encountered on mesic sites was 5.0 m^2 m^{-2} in a mixed fireweed-thimbleberry community. On hygric sites, the maximum LAI of thimbleberry communities was 10.1 m^2 m^{-2}. In these early seral communities, LAI may be approaching values expected in mature forest stands. LAI of climax western hemlock forests in the west Cascades of Oregon may range up to 14 m^2 m^{-2} (Gholz *et al.* 1975).

The following four models were tested for describing light attenuation by these communities (n=40):

1. $Ln(I_z/I_o) = -0.68 \times (LAI_1 + LAI_2 + LAI_3)$, $r^2 = 0.80$ $S_{y \cdot x} = 1.28$;
2. $Ln(I_z/I_o) = -1.12 \times LAI_1 - 0.66 \times LAI_2 - 0.83 \times LAI_3$, $R^2 = 0.84$ $S_{y \cdot x} = 1.59$;
3. $Ln(I_z/I_o) = -0.033 \times (C_1 + C_2 + C_3)$, $r^2 = 0.91$ $S_{y \cdot x} = 0.83$ (Figure 1);
4. $Ln(I_z/I_o) = -0.32 \times C_1 - 0.038 \times C_2 - 0.035 \times C_3$, $R^2 = 0.93$ $S_{y \cdot x} = 0.78$

where LAI_1, LAI_2 and LAI_3 represent leaf area index of fireweed, thimbleberry, and other species respectively and C_1, C_2 and C_3 represent percent cover of fireweed, thimbleberry and other species respectively.

Models using percent cover as independent variables gave better estimates of light attenuation than models based on LAI in these communities. Coefficients for percent cover of each species in model 4 are very similar while coefficients for LAI of each species in model 2 differ substantially.

Based on calculations from model 3 (Figure 1), 56% of full sunlight will reach ground level at 25% cover, 32% at 50% cover, 10% at 100% cover, and 4% at 140% cover. Emmingham and Waring (1973) report that Douglas-fir may regenerate and survive under coniferous canopies at light levels as low as 7% of full sunlight. Survival thresholds for light competition (levels of competition above which mortality occurs) may occur at very high levels of vegetation cover (100 to 115%). These levels were found under dense patches of fireweed and under continuous canopies of thimbleberry. However, seedling growth may be reduced and seedlings may become susceptible to physical damage at lower intensities of light competition.

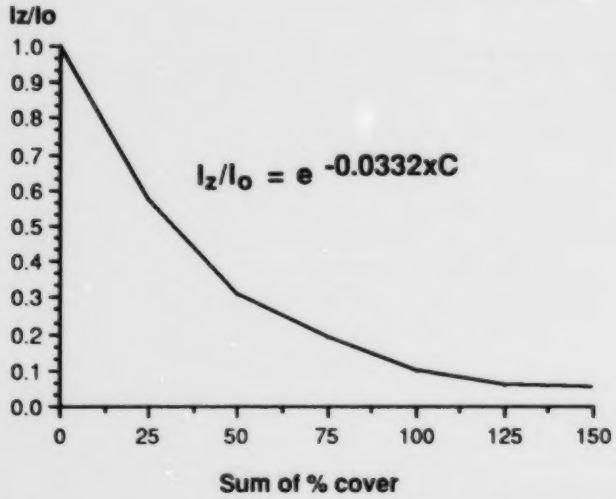

FIGURE 1. The relationship between light attenuation and vegetation cover as described by model 3. I_z/I_o indicates the proportion of full sunlight reaching ground level beneath vegetation canopies.

A simple model of photosynthetic responses of Douglas-fir needles was used to estimate hourly and daily net CO_2 assimilation of foliage for one day in July. Results indicate that: at 50% cover daily CO_2 assimilation is 74% that of fully exposed foliage; at 100% cover it is 50% that of fully exposed foliage; and at 150% cover foliage may achieve only 19% of the rate of daily CO_2 assimilation of fully exposed foliage. Survival and growth of seedlings will depend on the amount of assimilated carbon which is available for growth after deducting respiration by stems, twigs and roots and after deducting litterfall. The duration of the leaf area of deciduous canopies may also influence growth and survival. Evergreen conifer seedlings may be able to assimilate sufficient carbon during spring and fall periods, when the brush species are leafless, to sustain good growth. Vegetation cover may moderate summer air and soil temperatures and may benefit seedling growth and survival by reducing moisture stress and respiration rates.

Percent cover provided consistent estimates of light attenuation in these communities. Further study is required before applying these estimates of light attenuation to other species or in other areas. Objective estimates of percent cover may be required to ensure consistency. Since assessment of competition for light should consider the amount of vegetation overtopping crop seedlings, seedling and vegetation height should also be measured. Additional field data describing the physiological and growth responses of seedlings to resource availability and to competition are required to develop refined models of resource competition. Such models of competition are needed to assess the effects of differing intensities of competition on the survival and growth of crop seedlings, and for evaluating the potential benefits of vegetation control.

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Changes in Structure of Three Vegetation Complexes over the Growing Season and Their Effect on Competition for Light with Hybrid Spruce

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In the wetter portions of the Sub-Boreal Spruce Zone, near Prince George, B.C., shrubs and herbs quickly invade clearcut or rehabilitated sites after treatment with any of the commonly used site preparation techniques. Information gathered on these sites indicates that some invading species reach high levels of cover and height thereby significantly reducing light levels available to seedlings, often within one year of planting.

The actual level of light reduction caused by this vegetation, and the effect it has on the performance of the seedling, is not well understood. Silviculturists must know when seedling performance is being significantly reduced by light interception so that they can take action to eliminate the problem.

Numerous studies have been conducted to develop relationships between various measurements of the degree of overtopping or light interception by different competing vegetation complexes and the subsequent development of young tree seedlings. However, few studies have examined the development of different vegetation complexes over the growing season to establish the time of the growing season within which individual vegetation types overtop seedlings. Investigation of this development allows a comparison of the relative competitiveness for light of different vegetation complexes.

During the summer of 1987 the development, over the growing season (May 26 - August 12), of three different vegetation complexes (Thimbleberry/ Fireweed, Lady fern and Grass) were studied. The study also evaluated the effects that developing vegetation had on reducing photosynthetically active radiation and seedling growth. The studies took place at two sites (a five-year-old and a one-year-old plantation) in the Bowron River valley southeast of Prince George. The following weekly measurements were taken: percent cover, height and average distance of competing vegetation from seedling, background and beneath canopy light (P.A.R.), and seedling height, diameter and crown radius. The vegetation development was assessed using percent cover, height and competition index level (calculated by multiplying the percent cover by the height and dividing by the average distance of the inner edge of the vegetation from the seedling) for each major species in the complex.

All vegetation complexes were fully developed, or nearly so, by mid-July (Julian Day 195). Fireweed (*Epilobium angustifolium*) develops most rapidly, followed by nodding wood reed (*Cinna latifolia*), lady fern (*Athyrium filix-femina*) and thimbleberry (*Rubus parviflorus*) (Figure 1). Fireweed reached half of its maximum percent coverage by the beginning of June, whereas thimbleberry didn't reach this level until the third week in June. The competition index was consistent in predicting light levels (percent of background P.A.R.) measured at the midpoint of the seedling crown, for each vegetation complex at each site studied (Table 1). In all cases it was significantly related to measured light levels. Additionally the relationship between light levels and the competition index appears to be similar for each vegetation complex (Table 1 and Figure 2). This indicates that the main difference in the ability of these species to compete for light, is their rate of development over the growing season.

TABLE 1. Linear regression equations predicting light levels (measured as percent background P.A.R.) based on competition index (CI) value

Site[a]	Vegetation Complex	Equation	h	r^2	F
1	Thimbleberry/Fireweed	y = 169.6 – 17.6 ln (CI)	53	0.52	56.73[b]
1	Lady fern	y = 165.7 – 18.2 ln (CI)	146	0.60	217.94[b]
1	Grass	y = 154.0 – 15.7 ln (CI)	79	0.59	113.34[b]
2	Fireweed	y = 160.6 – 17.1 in (CI)	44	0.52	47.35[b]
2	Thimbleberry	y = 143.5 – 15.0 ln (CI)	20	0.78	66.32[b]

[a] Site 1 is the five year-old-plantation and site 2 is the one-year-old plantation

[b] Significant at p = 0.01

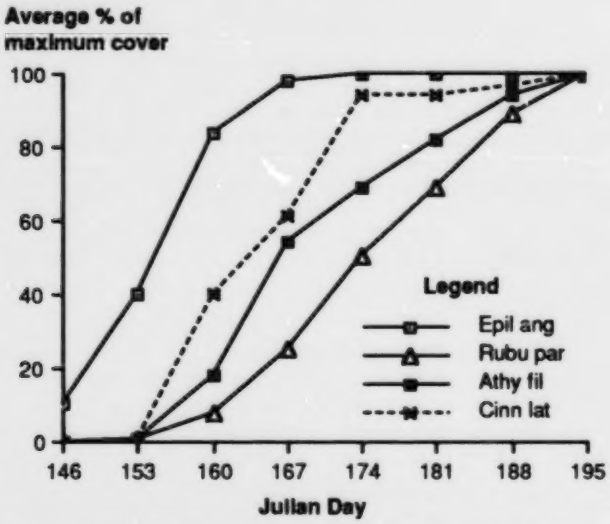

FIGURE 1. Development of vegetation cover (average percentage of maximum) for four plant species from May 26 (Julian Day 146) to July 14 (Julian Day 195).

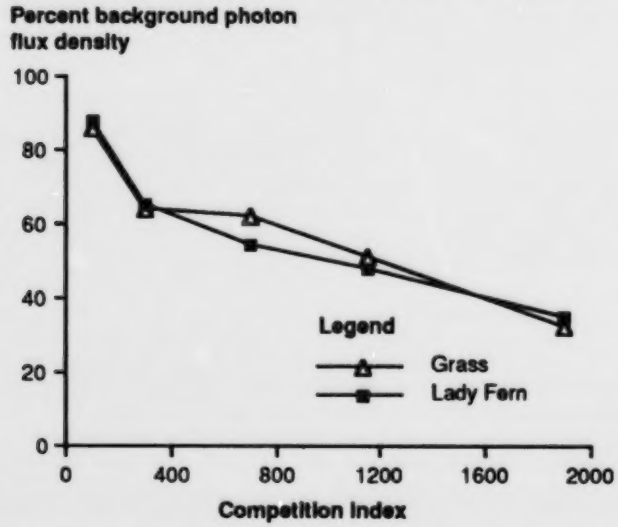

FIGURE 2. Relationship between light levels at the tree seedling height and amount and distribution of vegetation (as indicated by the competition index) for two vegetation complexes.

Duration and Intensity of Vegetation Control: Establishing Seedling Growth Potential

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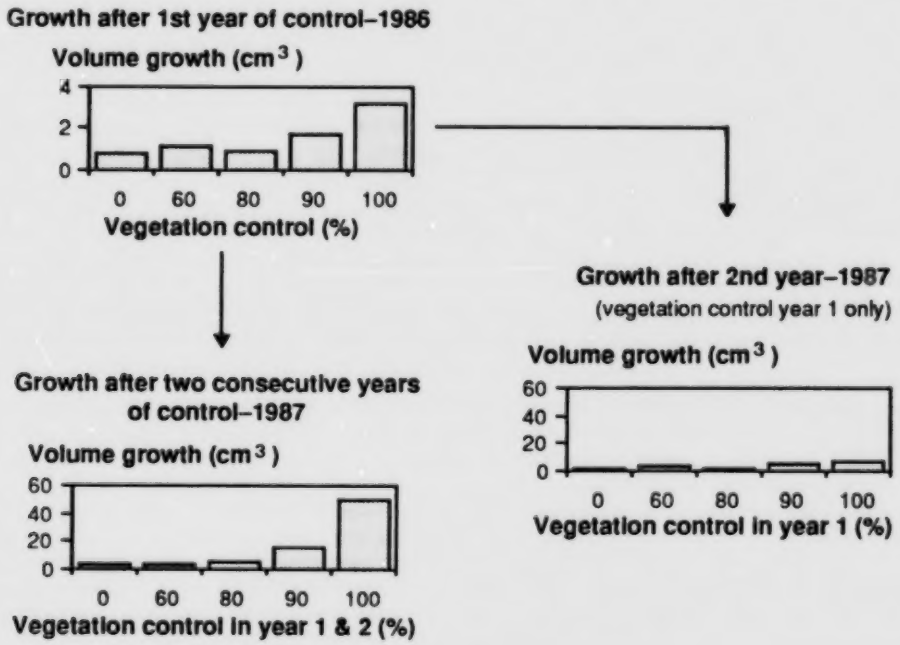
Douglas-fir seedlings subjected to duration (1 vs. 2 years) and intensity (0%, 55%, 75%, 90% and 100%) of vegetation control have exhibited a dramatic response to competition. Seedlings in plots receiving vegetation control in 1986 and 1987 had better height, caliper and volume growth than seedlings from plots receiving vegetation control in 1986 only. Seedlings from 1986 plots maintained the size differential established during the first growing season, although mortality increased in 1987. Growth parameters increased in 1987 with increasing quantities of vegetation control. Complete control of vegetation for 2 consecutive years increased height growth by 2.5-fold, caliper growth by 8-fold, and volume growth by a factor of 40. Interestingly, increasing control from 90 percent to 100 percent for 2 consecutive years increased second season height growth by only 25 percent, but increased caliper and volume growth by about 100 percent and 300 percent, respectively. Height/caliper ratios, a measure of seedling vigor, decreased with increasing percent control, falling from 65 to 50 for seedlings in 1986 plots, and from 65 to 37 for 1986/1987 plots. Figure 1 demonstrates the benefits in volume growth that can be achieved by 2 consecutive years of vegetation control, and the adverse effect of vegetation allowed to recapture the site in the second year after only 1 year of control.



NOTE: Vertical scale in 1986 vs 1987 volume growth data.

The magnitude of the response is a function of the degree and duration of resource limitation. this site was mesic, but the second summer was dry, particularly between late July and October. This coincides with the time when water and/or nutrient availability for diameter growth would be most limiting.

FIGURE 1. Comparison of seedling growth under varying degrees of vegetation control over two years.

Initial Vegetation Development Following Clearcutting and Slashburning in the Coastal Western Hemlock Zone of B.C.

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INTRODUCTION

In light of the well know variability in slashburning effects, and the need to be able to predict the effects if slashburning is to be properly applied, a study was begun in 1980 with the ultimate objective of developing models to predict slashburning effects on soils, streams and vegetation - of which vegetation is the focus of this report.

THE STUDY

The present study was conducted in that portion of the UBC Research Forest at Haney, 40 km east of Vancouver, lying in the drier maritime CWHa subzone. This area is generally gentle with relatively little relief, has shallow coarse-textured soils with forests dominated by western hemlock, western redcedar and Douglas-fir. Three distinct ecosystem types are present - the xeric or dry ecosystems on ridgetops with salal dominant in the understory, the mesic ecosystems on midslopes with mosses dominant in the understory, and the subhygric or moist ecosystems on lower slopes with sword fern dominant in the understory.

In this area three clearcuts were burned, one in each of 1974, 1983 and 1986. The 1974 and 1986 burns were paired with unburned clearcuts. The three burned areas are all immediately adjacent to one another and have the same soils, topography and climate, and contain identical ecosystems. The three burns covered a range of severities, with the 1974 burn the most severe (total fuel consumption = 16 kg/m^2, forest floor depth of burn = 5 cm), followed by the 1983 burn (total fuel consumption = 7 kg/m^2, forest floor depth of burn = 3 cm), with the 1986 burn the least severe (total fuel consumption = 4 kg/m^2, forest floor depth of burn = 2 cm).

Vegetation was destructively sampled for up to 7 years postburning (in the case of the 1976 burn) at the same phenological time each year, at the height of the growing season, using 1 m^2 plots. Plant biomass was determined after oven-drying (70°C).

RESULTS

The Influence of Burning on Plant Regrowth

Results from the 1974 and 1986 treatments indicated that total plant biomass was less on the burned than on the unburned areas (at least for the first 7 years following treatment in the case of the 1974 treatments, Figures 1 and 2), especially for species such as red alder, *Rubus* species and salal. However, some species, such as bracken and fireweed, produced more biomass in the burned than in the unburned areas.

The Effects of Slashburn Severity on Plant Regrowth

The total biomass in the first year postburn (the only year for which data for all three burns are available) decreased as burn severity increased, being greatest for the 1986 burn and least for the 1974 burn (Figure 3). However, the growing season weather in the first year postburn was drier and cooler for the 1974 burn, wettest for the 1983 burn, and warmest for the 1986 burn. These differences, together with others such as seed abundance, may have influenced plant growth. Thus the relationship between plant regrowth and slashburn severity must remain tentative.

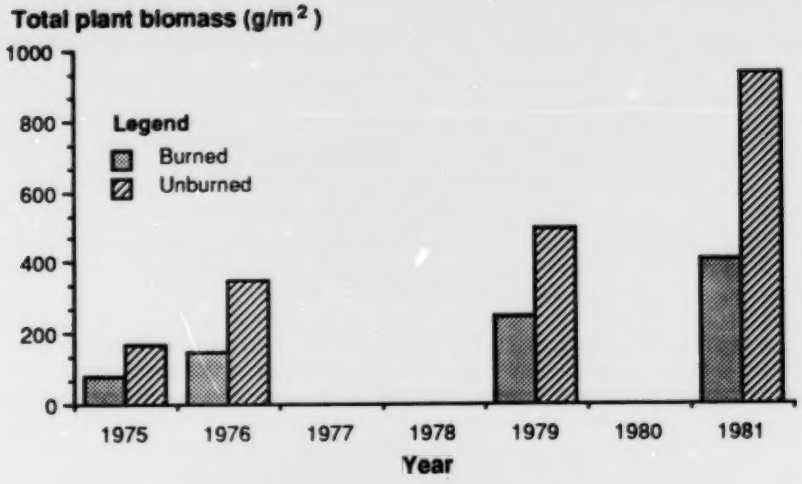

FIGURE 1. Total plant biomass in a burned and a nearby unburned area. Both areas were harvested in 1973, and one burned in 1974.

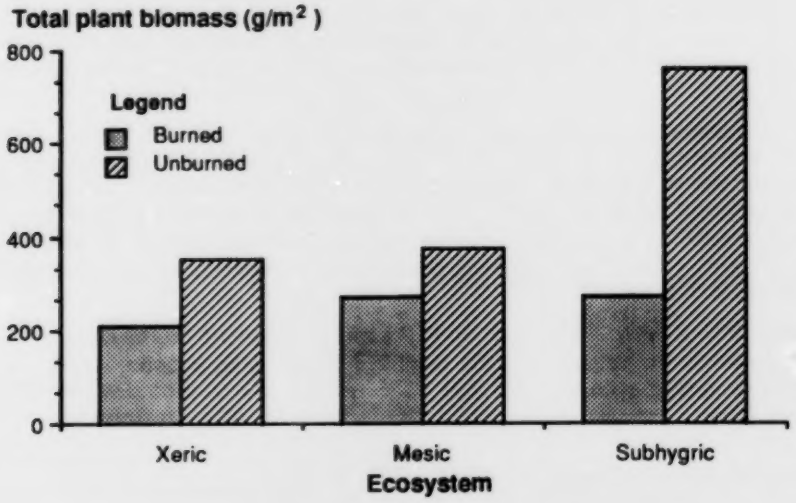

FIGURE 2. Total first year post-treatment plant biomass in a burned, and an adjacent unburned portion of a clearcut, with cutting and burning occurring in 1986

The Effect of Ecosystem Type on Plant Regrowth Following Slashburning

Results from the 1983 and 1986 burns indicated that total plant biomass increased from xeric to mesic to subhygric ecosystems, paralleling their site indexes (Figures 2 and 4). The biomass of some plant species followed the same trend as that for all the plants together. Notable exceptions were salal and bracken which produced the least biomass on the subhygric sites.

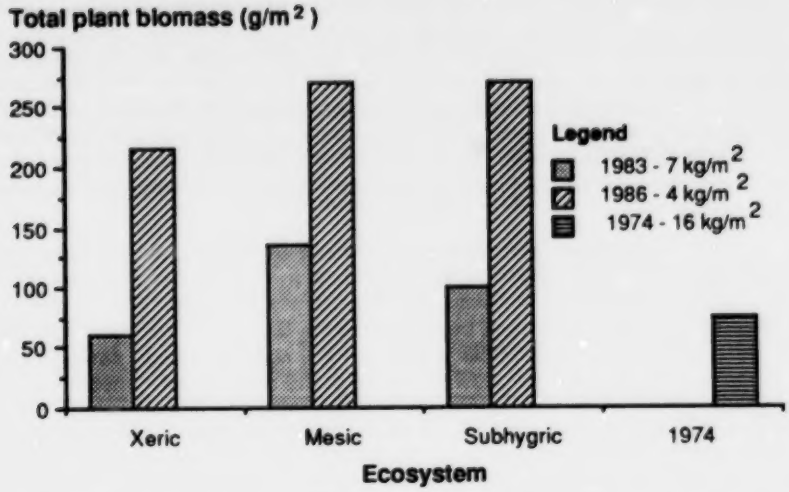

FIGURE 3. Total first year post-burn plant biomass for three different burns[1]

[1]Although data for the 1974 burn were not collected on an ecosystem-specific basis, comparison of the data for the 1983 and 1974 burns using the distribution of the three ecosystems within the 1974 burn area, indicates that the total first year plant biomass was generally lower for the 1974 than for the 1983 burn.

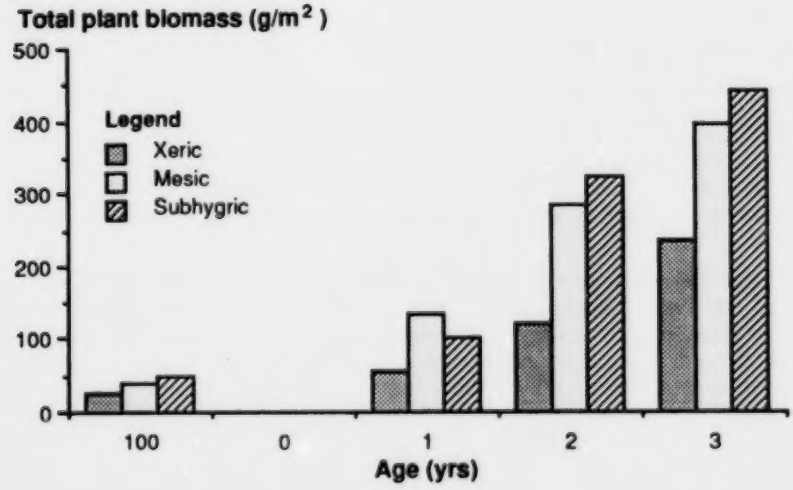

FIGURE 4. Total plant biomass in each of three ecosystems before and for 3 years after a 1983 clearcutting and slashburning

VEGETATION MANAGEMENT IMPLICATIONS

If vegetation competition with planted seedlings does become a concern, the dominant competing species will vary depending on the ecosystems present. Salal and bracken are likely to be more important on the drier sites, whereas fireweed, red alder and the *Rubus* species are likely to be more important on the moister sites. Salal and bracken on drier sites regenerate primarily from roots, rhizomes or seeds stored in the relatively deep forest floor, whereas fireweed, red alder and *Rubus* species on moister sites regenerate primarily from seed dispersal and roots or rhizomes in the mineral soil and, to a lesser extent, in the relatively thin forest floor.

Consequently, a severe slashburn which consumes most of the forest floor has a much greater likelihood of reducing vegetation competition in the drier than in the moister ecosystems. However, a severe slashburn on drier sites could adversely affect forest productivity. Before we can state with certainty that such slashburning would be more beneficial on the drier sites, we need to know the effect of different fire severities at different phenological stages on the relative growth rates of planted conifer seedlings and the competing plant species. However, due to the ecosystem - specific differences in the species regenerating after clearcutting in the CWHa, and in the locations of their propagules, ecosystem - specific vegetation management strategies may have to be different in different ecosystems.

CONCLUSIONS

1. In the CWHa subzone, there appears to be less plant biomass in a clearcut during the initial postharvesting years if the clearcut is slashburned, than if it is not burned.
2. In the CWHa subzone, the early growth response to clearcutting and slashburning of some important plant species which compete with conifer seedlings, depends on:
   a. burn severity (with plant growth decreasing as burn severity increases); and
   b. ecosystem type (with plant growth decreasing as ecosystem moisture level decreases, although some plants, such as salal and bracken, produce more biomass in the drier ecosystems).
3. There are still too many uncertainties to allow us to accurately predict the ecosystem-specific effects on vegetation competition of a slashburn of given severity at a given time.

The Relationship of Carbohydrate Content of Plants to Their Ability to Sprout After Mechanical Treatment

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Carbohydrates in woody plants can be found in many different forms and are critical to plant development and physiology. Produced during photosynthesis, carbohydrates account for approximately 75% of woody plant dry weight, and form the basis for most organic compounds found in woody plants (Kramer and Kozlowski 1979). Carbohydrates play important roles in a number of processes, not the least of which are growth and respiration. Studies of energy reserves in woody plants have generally focused on sugars and starch; the latter being primarily a carbohydrate reserve utilized for respiration and growth when the products of photosynthesis are inadequate to meet physiological demands. The cyclical nature of carbohydrate build-up and depletion is well-documented for a wide-variety of woody species. It is this pattern of fluctuating carbohydrate levels which has been of interest to some investigators exploring ways of minimizing sprout development following mechanical damage to the plant.

When the above-ground portion of a sprouting woody plant is damaged by mechanical means (e.g., cut by chainsaw), the photosynthetic surface area is either reduced or largely eliminated. As a consequence, when suppressed buds respond and active shoot elongation begins, the plant is forced to utilize a portion of its carbohydrate reserves. Conceptually then, it would seem possible to minimize sprout growth by timing mechanical damage to occur when carbohydrate reserves are at a low point, thus reducing sprout growth. This would seem true for both deciduous and evergreen species although it should be recognized that patterns of build-up and depletion may be quite different particularly since some evergreen hardwoods probably carry-on photosynthesis during winter months. Just how important carbohydrate reserves are to sprout development is not clear as some studies have found no correlation between carbohydrate content and sprout development (Wenger 1953, Vogt and Cox 1970).

Despite differences of opinion, a number of studies have reported that time of cutting has an effect on sprout response (Jones and Laude 1960, Kay *et al.* 1961, Harrington 1984). For additional details see Hobbs (1986), and Hobbs and Radosevich (1987). Whether such responses can be attributed to carbohydrate levels is questionable as sprouting is most likely the result of several factors acting in concert.

The idea of decreasing sprout development by reducing carbohydrate reserves has merit although several treatments may be necessary to achieve the desired effect. However, from an operational perspective, this is often not a realistic option because of the high costs associated with such operations. One of the biggest handicaps is that during the growing season, particularly in conditions of full sunlight, sprout growth and carbohydrate replenishment probably occur very rapidly thus necessitating two or more treatments over a short period of time. A plausible difficulty in trying to deplete carbohydrate reserves is that once some threshold level of photosynthetic surface area has developed, additional growth is probably driven by current photosynthate, rather than carbohydrate reserves. Therefore, one modification might be to treat hardwoods one or two years prior to conifer harvest so that sprouts are forced to develop in conditions of decreased light under a relatively closed canopy.

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Chemical and Manual Control of Thimbleberry (*Rubus parviflorus*): A Rate and Timing Trial

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This ongoing trial is located at Sharpe Creek, near Moricetown, B.C. in the Interior Cedar-Hemlock Zone, Hazelton variant. The site lies on a fluvial bench above the Bulkley River with an even, gentle slope and southern aspect. Thimbleberry dominated the site with an average cover of 35% and an average height of 45 cm in 1986. Four methods of control, four treatment dates and 20 replicates were used for a total of 320 plots in a completely randomized design.

Treatment plots were 20 m^2 (4 m X 5 m) with a circular, 5 m^2 assessment plot in the centre. Roundup®, (glyphosate) was applied at 1.4 and 2.1 kg ai/ha with a delivery rate of 112 L/ha using a CO2-powered backpack sprayer and an eight nozzle, four-metre long boom. Manual cuttings were completed following the herbicide application using Husqvarna 165R brush saws.

At the end of the first full growing season, both time and method of treatment were found to be significant. Both rates of Roundup application on the first treatment date (June 26) resulted in only marginally effective brush control (Figure 1). The Roundup®, treatments at the later three dates (July 17, August 7 and August 28) were more effective and exhibited good to excellent control of the target species. The August 7 treatment date proved to be the most effective and while the higher rate of Roundup®, (2.1 kg ai/ha) did provide greater control, it was not significantly different from the lower rate (1.4 kg ai/ha). Manual control was found to be ineffective on all four treatment dates (Table 1) and in most cases resulted in a percent cover which was not significantly different from the controls.

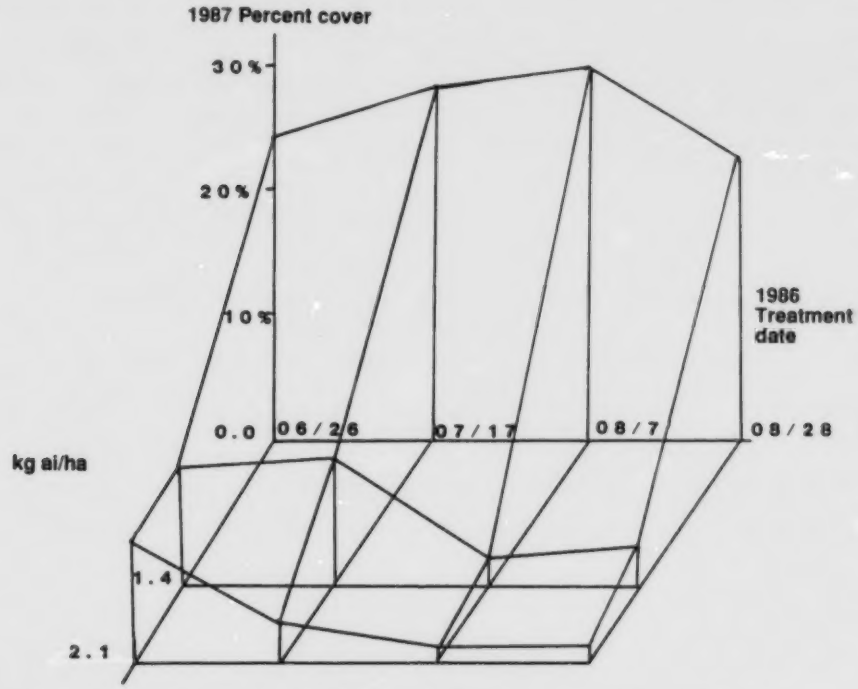

FIGURE 1. Thimbleberry cover versus application date and glyphosate rate

The preliminary results of this trial indicate that the timing of chemical thimbleberry control operations have a significant influence on the success of those operations. Greater long term control can be achieved by applying Roundup®, (glyphosate) later in the season, after meristem elongation is complete. The operational manager can realize substantial savings by using lower chemical concentrations and proper treatment dates.

TABLE 1. Thimbleberry cover versus application date and treatment option

Treatment	End of season % cover by treatment date*			
	June 26	July 17	August 7	August 28
Control	24.3 A	28.4 A	30.0 A	22.9 A
Manual cutting	25.8 A	17.2 B	28.5 A	27.0 A
1.4 kg ai/ha	8.8 B	10.0 C	2.1 B	3.0 B
2.1 kg ai/ha	8.8 B	1.8 D	0.4 B	1.9 B

* means not followed by a common letter are significantly different (P = 0.05)

Response of Vegetation to Mechanical Site Preparation Treatments in North Central British Columbia

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INTRODUCTION

This paper reports the results of three mechanical site preparation research trials. Two were done in the Wet Cool Central (SBSj) subzone and the third study was initiated on the Moist Cool Southern (BWBSc) subzone and in the Moist Cold Central (SBSi) and SBSj subzones.

Blade Scarification, Mixing and Clipping in the SBSj Subzone (McMinn 1972-1985)

This study was located on a Devil's club site (SBSj/07) at McGregor Camp, east of Prince George. Treatments were:

1. severe scalping by blade scarification;
2. mixing to 6 cm with a garden rotovator;
3. vegetation clipping 3 times during each of the first two growing seasons; and
4. a control.

Hybrid spruce 2+0 BR seedlings were planted on all treatments.

Results are summarized in Figures 1 and 2. Scarification provided good vegetation control, but tree growth was poor, and the mineral soil exposed was rapidly covered with willows and birch which had densely overtopped the spruce by year 13. Clipping provided the best vegetation control, with the best spruce performance. Mixing provided poor vegetation control, but seedling growth was good. Control plots had poor vegetation control and poor spruce performance. Willow and birch did not overtop seedlings on the clipping and mixing plots. The seedbed formed by the undisturbed humus of the clipping plots and the mixed surface of the mixing plots was apparently not as favorable for willow and birch as the mineral soil of the blade scarified plots.

In summary:

1. while vegetation management is not the only factor causing these differences in performance after 13 years, it seems to be important;
2. what appeared to be free-to-grow at 5 years (scarified treatment) was not at 13 years; and
3. from year 5, the clipped and mixed plots showed significantly greater seedling performance than the control; the scarified plot did not.

Blade Scarification and Mounding in the SBSj Subzone (McMinn 1982-1984)

This study took place at Stony Lake, southeast of Prince George. Treatments were:

1. blade scarification;
2. mounding with 2, 6 and 12 cm caps of mineral soil; and
3. control.

Hybrid white spruce 2+0 BR seedlings were planted on all treatments.

Results are summarized in Figures 3 and 4. Vegetation was controlled by mounds and blade scarification. Vegetation control was greater in mounds with a thick cap than with a thinner cap. Vegetation control on scarified plots was best. Vegetation competition was greatest on the control plots.

Tree height was greatest on thick mounds, less on small mounds, and least and not significantly different on scarified and control plots.

In summary:

1. inverted humus mounds can suppress competing vegetation if the mineral soil capping is deep enough (as with other treatments. However, the effects of mounding on the seedling go far beyond controlling vegetation – soil temperature, moisture, aeration and nutrient availability are all altered);
2. while vegetation management is not the only factor causing these differences in the performance after 3 years, it seems to be important; and
3. as with the first study, scarification, while providing good vegetation control, does not significantly change seedling height growth from the control.

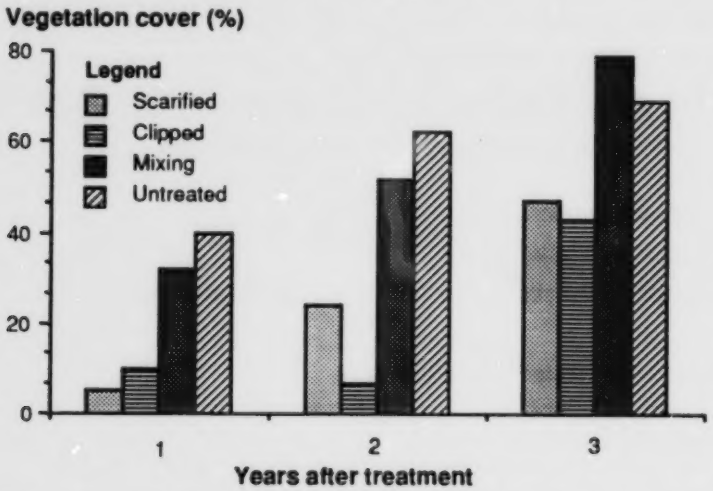

FIGURE 1. Total vegetation cover after blade scarification, mixing and clipping site preparation treatments

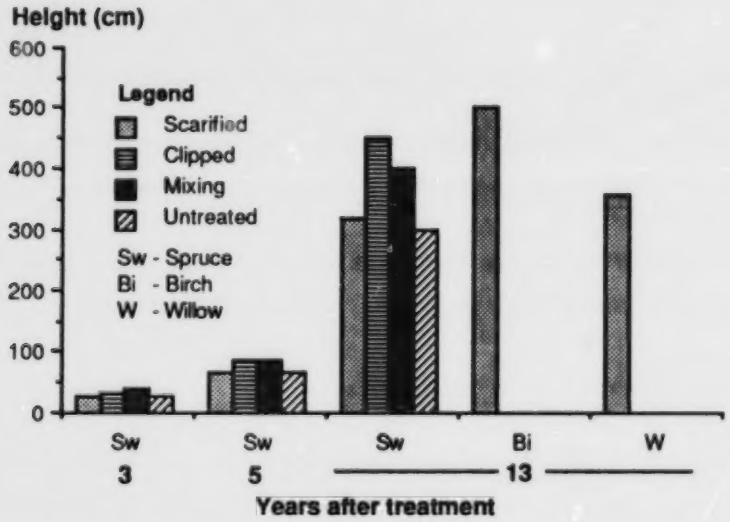

FIGURE 2. Spruce seedling/sapling height after blade scarification, mixing and clipping site preparation treatments

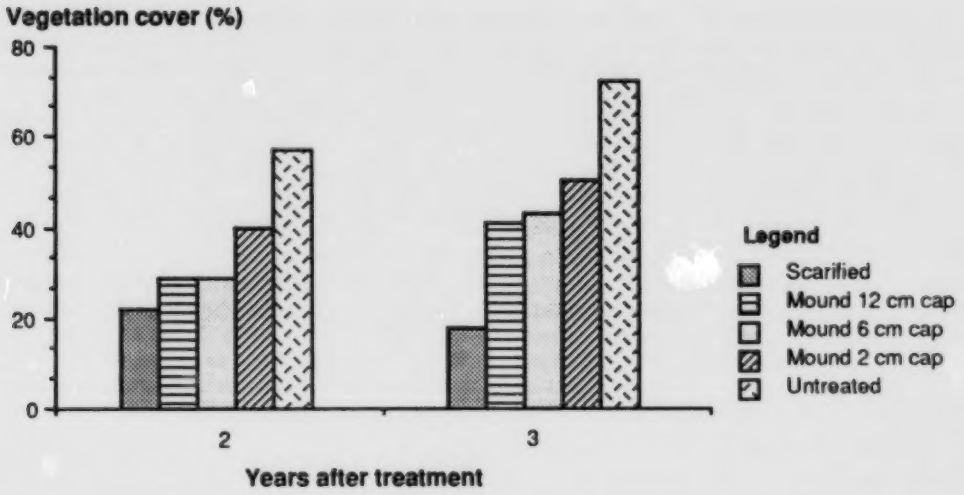

FIGURE 3. Total vegetation cover after blade scarification and mounding site preparation treatments

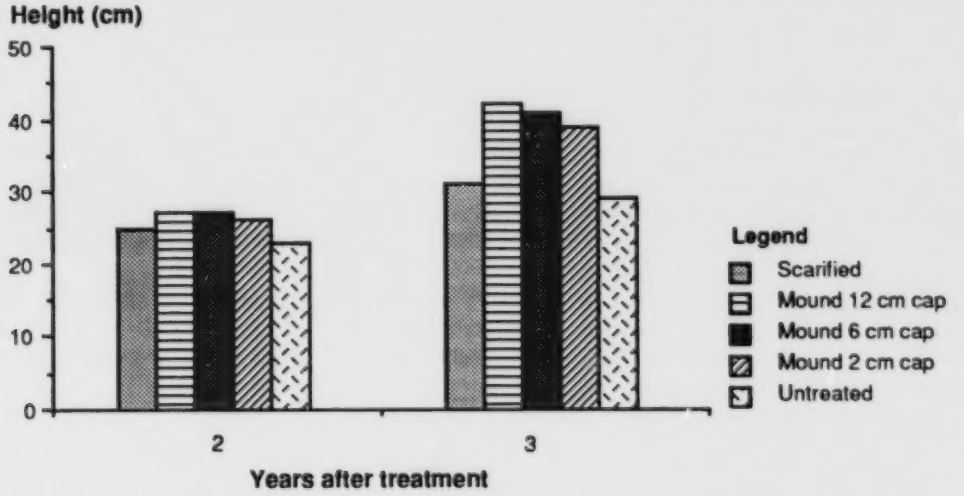

FIGURE 4. Spruce seedling height after blade scarification and mounding site preparation treatments

Various Site Preparation Techniques in the SBS and BWBS Zones (Bedford *et al.* 1986-1987; FRDA 1.10)

This study took place in four locations: at Iron Creek northwest of Fort St. John, at Stewart Lake northwest of Dawson Creek, at Mackenzie and at Kluskus, south of Vanderhoof.

The eight mechanical site preparation methods tested in these trials were:

1. mounders (the Bracke, Sinkkila with and without fertilizer applications, and Ministry mounders);
2. patch scarifiers (the Bracke scarifier with and without fertilization applications, and the Sinkkila);
3. plows (the V-blade and breaking plow); and
4. hydraulically powered disc trenchers (Donaren 180D).

Fertilizer was 20 g/seedling of 18:6:12 Osmocote®. Herbicide plots were treated with 2.5-3.0 kg ai/ha of Visions®, and control plots were set up at each site. Hybrid spruce 313 PSB stock was planted on all treatments at Mackenzie, Stewart Lake and Iron Creek, and lodgepole pine 211 PSB was used at Kluskus.

Ten 2000 cm^2 seedling-centred plots were situated within each of the five replicates of each treatment at each site, giving 50 plots/treatment/site. Each plot was scored for total percent cover of vegetation greater than 20 cm (i.e. vegetation considered to be of sufficient height to compete with the seedlings for available light), total percent cover of vegetation less than 20 cm, species present, their average height, and their distance from the seedling. A simple competition index was calculated from these data. Results are shown in Table 1.

TABLE 1 Total % cover greater than 20 cm, total % cover less than 20 cm, and competition index; values sharing a common letter (a, b, c or d) are not significantly different (p=0.01, Duncan multiple range tests)

Location	Treatment	Total % cover vegetation > 20 cm	Total % cover vegetation < 20 cm	Competition Index[1]
Stewart Lake	herbicide	5.275 a	13.250 a	21.130 a
	Ministry mounder	9.886 a,b	6.795 a	46.213 a
	breaking plow	16.180 b,c	10.320 a	59.293 a
	Bracke mounder	19.731 c	8.115 a	85.834 a
	Bracke patch & fertilizer	42.840 d	9.220 a	264.401 b
	Donaren	47.620 d	8.760 a	268.150 b
	control	47.760 d	14.040 a	335.546 b
	Bracke patch	48.380 d	8.320 a	274.807 b
Kluskus	Ministry mounder	4.720 a	4.780 a	27.916 a
	V-blade	5.280 a	8.780 a	16.501 a
	Sinkkila	7.900 a	10.640 a,b	34.044 a
	control	10.490 a	17.408 b	43.305 a
Mackenzie	herbicide	4.960 a	24.840 b	38.356 a
	Bracke mounder	9.109 a,b	13.087 a	26.762 a
	Ministry mounder	13.157 a,b,c	11.530 a	85.883 a
	V-blade	13.800 a,b,c	24.040 b	84.534 a
	Bracke patch	18.700 b,c	22.940 b	118.317 a
	control	20.640 c	45.420 c	112.496 a
Iron Creek	herbicide	4.660 a	11.540 a,b	14.910 a
	Ministry mounder	8.180 a	6.820 a	50.394 a
	Bracke mounder	11.560 a	11.100 a,b	49.170 a
	breaking plow	14.575 a	8.350 a,b	55.739 a
	Bracke patch	26.080 b	13.660 a,b	171.342 b
	control	32.340 b	14.660 b	215.358 b

[1] Competition Index = $\frac{\text{\% cover of vegetation greater than 20 cm x average height of vegetation}}{\text{distance of nearest vegetation to the seedling}}$

The Ministry mounder provided good vegetation control on all sites, producing low height, high caliper seedlings at all sites except Kluskus, where it produced low height, low caliper seedlings that had high mortality. The Bracke mounder provided good vegetation control on all sites; seedlings were medium to low in height and had low caliper. Vision® provided excellent control of competing vegetation on all sites; seedlings had medium to high height and medium to large caliper on all sites except Mackenzie, where height growth was poor. Complete control of competing vegetation has only been achieved at the cost of significant frost damage on several of the sites, and this explains, in part, the short Mackenzie seedlings. The Sinkkila mound resulted in poor seedling performance on all sites while the Sinkkila patch, on the Kluskus site, produced good caliper and height growth. The Bracke patch provided poor vegetation control on all sites and seedlings on the patches showed moderate to good height growth, with medium caliper. The Donaren provided poor vegetation control; seedlings showed medium height and caliper growth on all sites tested. The V-blade produced poor vegetation control, but was associated with excellent seedling height and caliper growth on the two sites (Kluskus, Mackenzie) where it was tested. The breaking plow resulted in good vegetation control and medium height and good caliper on the two sites (Iron Creek, Stewart Lake) where it was tested. Seedlings on control plots were tall and thin in the BWBS, and short and thin in the SBS.

SUMMARY

In the first two trials reported, there is a strong correlation between vegetation control and seedling performance. However, this correlation is not completely consistent, and it seems obvious that some forms of vegetation control (especially blade scarification) may reduce vegetation competition and decrease seedling performance.

In the third trial, high CI's are associated with tall, thin seedlings, and low CI's with shorter, stockier seedlings.

Mounding provides good vegetation control and increased seedling performance (either height or caliper increases over control) on most sites tested. In some areas, though, mounding is not practised due to the hostile seedling environment created by fine-textured mounds and/or extremely dry sites. As with any of these techniques, the site, and particularly the soils, should be understood before a machine is prescribed.

Short-term results will not provide all the answers for vegetation managers. In at least one of these trials, site preparation methods designed to control competing vegetation may have increased vegetation competition, and a site which appeared to be free-to-grow at five years was not later.

A Test of the "Resource pre-emption" and "Resource depletion" Models of Plant Competition in Mixtures of *Pinus ponderosa* and *Calamagrostis rubescens*

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One model of plant competition, the resource pre-emption model, is often used to explain the development of positive skewness in frequency distributions of plant size. This model states that large plants competitively suppress smaller neighbors, but not vice versa. The outcome is size-dependent relative growth rates that subsequently generate positive skewness in frequency distributions (Westoby 1982). This model is in contrast to the resource-depletion model which states that competition affects plants in proportion to their initial size. Relative growth rates in this model would not be size dependent and the skewness of a size distribution would remain constant with time. While the models have most often been applied to monocultures, it is possible to use analogous ones in the study of interspecific competition.

The validity of these models was tested in stands of *P. ponderosa* growing in monoculture and in mixture with *C. rubescens* in northwestern Montana (see Petersen 1988). The frequency distributions of stem volumes became positively skewed more quickly, and remained more highly skewed in the mixture than in the monoculture. But competition from *C. rubescens* reduced the relative growth rates by the same amount for trees of all initial sizes. Thus, the size-dependent relative growth rates predicted by the resource pre-emption model can not be used to explain the more asymmetric size distribution in the mixture, and it is rejected in favor of the resource depletion model. *C. rubescens* did increase the variation in relative growth rate of *P. ponderosa*, presumably due to variation in the spatial arrangement of *C. rubescens* around individual trees. This change in the relationship between variance in growth rate and initial size provides an alternative explanation for greater skewness in mixtures, as shown in work by Hara (1984).

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Forest Vegetation Management on Coastal Alluvial Sites: The Skeena and Kitimat Valley Experiments

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Five years of field experimentation near Terrace, B.C., have evaluated a number of forest vegetation management techniques potentially useful for coniferous reforestation. Early studies examined the species composition and growth rates of a number of early seral communities to determine the amount of competition afforded operational reforestation stock, and the susceptibility of the target species to various herbicides. Species composition favoured the use of glyphosate, which was tested on two sites. Five year results at Kwinitsa showed large increases in total height and leader growth of Sitka spruce, and excellent control of competing vegetation. Use of glyphosate up-river in the Northwestern Transitional Interior Cedar Hemlock Zone - Hazelton variant ICHg3 was less successful, and potentially undesirable species shifts were observed. Prescribed fire was used to rehabilitate older, brush-encroached sites beginning in 1983. Early trials were unsuccessful, but later attempts to burn these multi-storied alder-dominated brush fields, were successful when the Nalbeelah test site was felled, slashed and burned. The subsequent regeneration of competing species has been studied, and two other successful burns were conducted in 1987. Mechanical site preparation (MSP) combined with grass seeding has also proven successful. Creeping red fescue has promise as an alternative species capable of occupying the site while excluding other, more aggressive native species. Early reaction of large planting stock on MSP/grass-seeded sites was substandard, but third year response of Sitka spruce has been dramatic. The use of larger planting stock has also been successful, particularly when vegetation press and small mammal damage are a problem. The minimum recommended size stock for these sites is a PSB 415 1+0 Sitka spruce. Trials with more tolerant conifers have been unsuccessful on two locations, where Sitka spruce and western redcedar were compared on heavily disturbed and lightly disturbed sites.

Douglas-fir and Red Alder Competition in Mixed and Monoculture Stands

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Competitive interactions between crop trees and hardwoods are of significant economic and ecological importance to vegetation management. Implementation of vegetation management practices often involves the manipulation of the competitive environment of crop trees, through the modification of weed abundance, tree spacing and the physical environment. Development of models which quantify the effects of tree spacing and weed abundance, as well as addressing the mechanisms underlying the competitive effects, will aid in management decisions and facilitate more accurate predictions of tree performance in a wide array of sites and competitive regimes.

Red alder is a fast-growing nitrogen-fixing weedy associate of Douglas-fir in many regions of the Pacific Northwest. Interest in the potential for mixed planting or alternate planting with alder to enhance the nutrient status of Douglas-fir systems has stimulated research on the association between these two economically important species. The primary objectives of this experiment are:

1. to quantify the separate influences of intra- and interspecific competitive interactions between these two species; and
2. to identify and quantify potential underlying mechanisms of competition.

Potential mechanisms of conifer-hardwood interactions are assessed through the analysis of the interrelationships between competitive environment, resources, physiological indicators and growth.

The experimental design is based on fundamental yield-density relationships and provides a wide range of competitive regimes through the direct and systematic manipulation of both alder and Douglas-fir densities. Seedlings of both species were planted in monoculture densities of 1, 2, 4, 8 and 16 trees m^{-2}. Mixed stands were composed of all possible pairwise combinations of the monoculture densities, resulting in a two-dimensional density gradient of competitive regimes.

Tree size, as well as indices of resource availability and physiological status, were measured and analysed in response to competitive regime. Tree size variables included height and stem diameter measured at 2 cm above ground level. Relative growth rates were calculated from the relationship between logarithmically-transformed monthly estimates of stem volume and time. Soil moisture content was measured monthly using a neutron probe. Soil moisture depletion was calculated by subtracting the estimates of soil moisture content at the end of the growing season from those at the beginning of the season. Light availability was measured by taking photographs vertically through the canopies with a fisheye lens, at three heights from ground level, with high contrast film. These photographs were then digitized by computer to provide estimates of the proportion of full sun intercepted by the leaves in the canopy. Leaf water potential provided a physiological indicator and was measured with a pressure chamber.

Tree size parameters were sensitive to competitive regime. Stem diameter, stem volume and relative growth rate of Douglas-fir in monoculture declined with increasing Douglas-fir density. In mixtures, increasing red alder density resulted in a reduction of Douglas-fir relative growth rate. The effects of both species' density on growth reduction were not strictly additive. At low densities of Douglas-fir, reductions in growth of Douglas-fir, induced by alder, were greatest and Douglas-fir had little influence on its own growth. At high alder densities, increasing the density of Douglas-fir resulted in an increase in Douglas-fir growth rate. Growth of red alder was influenced primarily by its own density, and at low alder densities, increasing Douglas-fir density resulted in a moderate decline in alder growth rates. The most significant effect that Douglas-fir had on red alder, was a marked suppression of red alder leaf area, illustrating a key influence of the understory conifer seedlings on overstory canopy structure. These results indicate that competitive interactions between these two species are complex and involve various feedback processes between density and growth of both species.

Light availability was significantly affected by competitive regime and was related to the canopy structure of the dominant red alder seedlings. In alder monocultures, increasing alder density resulted in a decrease in light penetration through the canopy, which was correlated with an increase in leaf area index. Addition of Douglas-fir to the stands, however, increased the complexity of this response. In mixed stands, light availability declined when increasing the alder densities from 0 to 4 m^{-2} and then increased in treatments with alder densities 4 to 16 m^{-2}. Increasing Douglas-fir density resulted in an increase in light availability, which was correlated with the suppressing effect of Douglas-fir on red alder leaf area.

Soil moisture depletion was constant over all treatments. Increasing the densities of trees is hypothesized to result in a decrease in the amount of moisture consumed by each tree. Predawn leaf water potential served as a physiological response to the soil moisture resource regime. Increasing the density of either species resulted in elevated levels of water stress of both species late in the growing season.

Species interactions which influence conifer yield are complex and involve feedback processes between growth and density of each species. Red alder leaf area index and canopy structure were principal determinants of light resources, and were significantly modified by the densities of both species. Resource and physiological variables were also highly correlated with competitive regime. Specific mathematical functions for the interrelationships of tree size, resource dynamics, physiological indicators and competitive regime were successfully developed for this highly controlled density study. Implementation of such an approach under field conditions remains as the next challenge to this research. Competitive interactions are not always as important in determining conifer performance as other factors such as herbivory, disease or microsite heterogeneity. These variables, along with variables such as stock type, site quality, rainfall, soil depth, canopy structure and competitive environment could be incorporated into more predictive models for conifer performance.

Impact of Competing Vegetation on Site Water Balance

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Competition for soil water between undesired vegetation and crop trees can drastically affect the survival and growth of the crop tree. An unfavourable leaf water status can substantially reduce photosynthesis and disrupt other processes in the cell. Plants have developed a variety of strategies to regulate their internal water status to maximize their chances for survival and growth. We need to understand the physics and physiology involved in these strategies if we are to enhance seedling water status through the manipulation of the competing vegetation.

Water moves from the soil into plant roots and from the roots to the leaves due to differences in water status (potential) between these points. The soil water supply, and thus uptake, depends on soil depth, texture, precipitation and water lost by soil-surface evaporation and to other plants. The plant factors effecting water uptake are root density and rooting depth. The amount of water lost through transpiration depends upon the atmospheric demand for water (solar radiation, air temperature and humidity), leaf water potential, leaf area per plant and the degree of stomatal opening (stomatal conductance). During the daytime, atmospheric demand is often much greater than water uptake resulting in the drying of the leaves and a decrease in leaf water potential. If leaf water potential begins to decrease below a tolerable level, e.g. about -2 MPa (20 bar) for Douglas-fir and salal, -1.6 MPa for spruce and -1 MPa for alder, the stomata will start to close to reduce water loss.

The vapor pressure deficit (vpd), a measure of the dryness of the air, is a good indicator of the evaporative demand of the atmosphere. As the air dries (vpd increasing) the stomata of most species of plants of concern to forestry begin to close (Figure 1; a vpd of 3 kPa represents air of 15% relative humidity and 27°C.). Stomatal conductance is also sensitive to soil drying, decreasing rapidly at soil water potentials drier than -0.1 MPa (1 bar). Light and overnight air temperature also influence stomatal conductance. Soil temperature can affect the rate of water flow to the plant and in the root system. In summary, the short term control of transpiration is by the stomata, while the amount of leaf and root are a way that plants can control water status over the longer term. Furthermore, later in the season plants can often tolerate a lower (drier) leaf water potential through the process of osmotic adjustment.

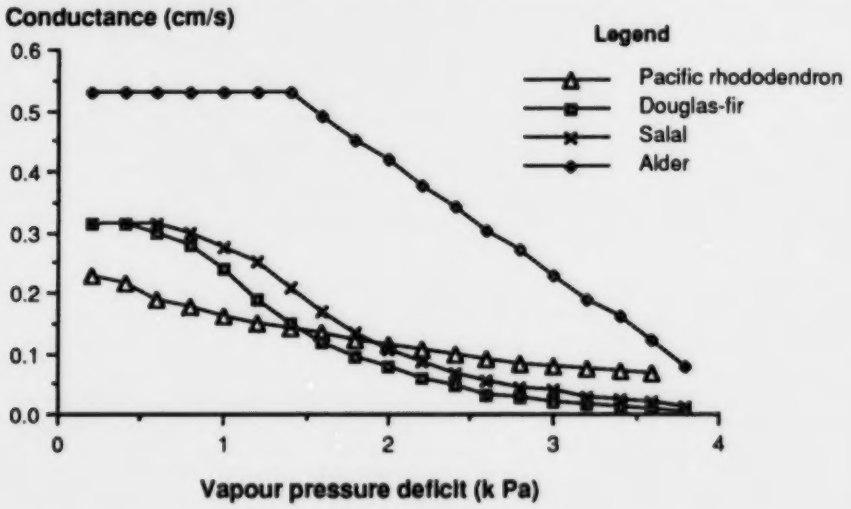

FIGURE 1. Stomatal opening (conductance) as a function of air dryness (vapour pressure deficit) for alder, salal, Douglas-fir, and Pacific rhododendron.

An example of the effect of competing vegetation on site water balance and, thus, the water available for seedlings is presented in Figure 2. The data are the average soil water status of the top 0.2 m of a dry, rocky site near Pemberton. A large amount of competing vegetation at this site results in rapid drying of the soil once the spring rains have ended. Seedlings at this site would suffer severe water stress for much of the summer. Removal of all the vegetation results in water loss by only soil surface evaporation. As the top 5 cm dries, it acts as a mulch, greatly reducing the soil evaporation rate and helping to maintain a favourable water status in the seedling root zone through much of the growing season. The third line on the graph shows that at this site only a small amount of vegetation is required for the production of substantial drying of the seedling root zone. Deeper depths stay moist for a longer period of time.

The continued addition of vegetation to a site does not result in the continued increase in the daily transpiration rate. The maximum transpiration from the vegetation is limited by the energy available to evaporate the water. As more leaf material is added, the lower leaves of the canopy become shaded and their transpiration rate is reduced. Large leaf areas exist only at sites where a large water supply (through rainfall, seepage or a deep soil) is available to maintain transpiration through much of the summer.

Competition for moisture does not end when the tree over-tops the competing vegetation. For example, since the stomata of the salal close more slowly than the Douglas-fir in response to increasing vpd and soil dryness, a salal understory can use a large amount of water. Figure 3 shows the diurnal transpiration of a 30-year-old Douglas-fir stand (15 m tall) on the east coast of Vancouver Island. The trees have twice as much leaf area as the 0.6 m tall salal understory. The initial assessment of this situation might be that the shaded salal understory would have only a minor effect on the site water balance. Figure 3 indicates that this is not so, particularly for days when the vpd reaches 3 kPa. Douglas-fir has a high transpiration rate during the morning when the soil is wet. However, reduction in the leaf water potential and the need to reduce transpiration to match root uptake during the day, results in the partial closure of the stomata and a decrease in transpiration in the afternoon. The Douglas-fir has a much greater decrease than the salal. When the soil is dry (lower lines), the salal uses more water than the Douglas-fir. Over the whole of the growing season the salal used about 40% of the available water. The removal of the salal from around a number of trees resulted in an improved water status of the Douglas-fir needles, and a greater transpiration rate, photosynthesis rate and stem diameter increment than in the untreated trees.

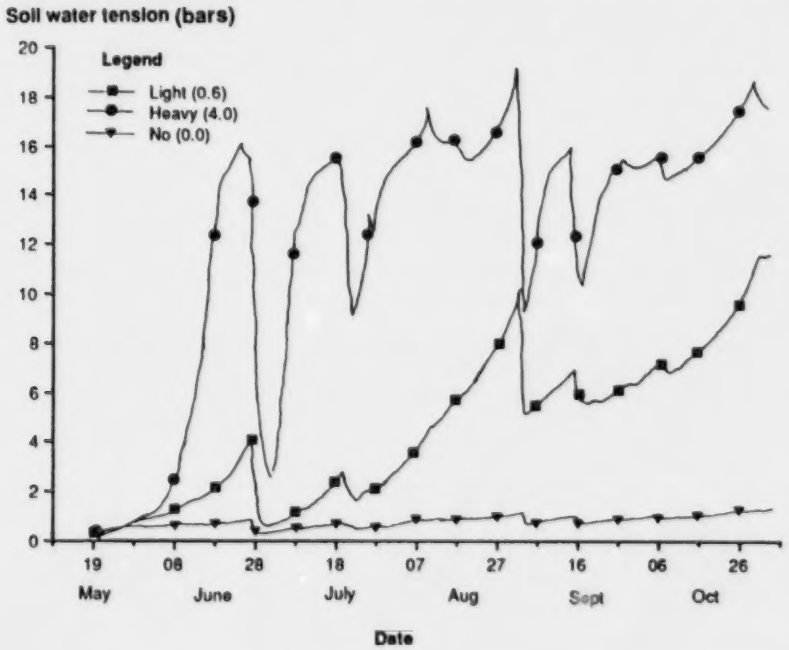

FIGURE 2. Seasonal trend of seedling root zone soil water status for three levels of vegetation competition; heavy, light, and no cover.

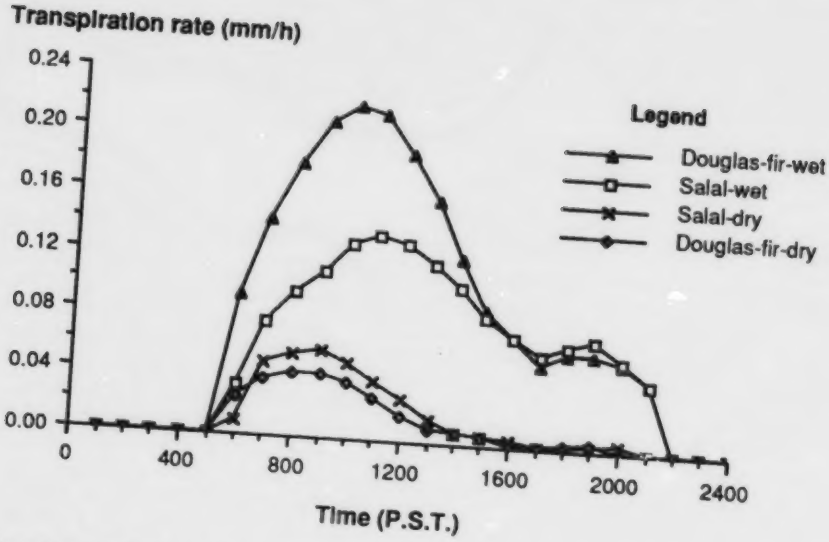

FIGURE 3. Diurnal transpiration of 30-year-old Douglas-fir trees and a salal understory for wet and dry soil conditions.

Response of Vegetation to Herbicides in the Nelson Forest Region [1]

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BACKGROUND

When this project started, locally developed weed species/treatment efficacy tables for forest-use herbicides did not exist for the Nelson Forest Region of British Columbia. There were also two impediments to the immediate application of similar tables developed in the adjacent States: species of concern in the region (e.g., *Rhododendron albiflorum*) were not included; and there were considerable and justifiable reservations to the immediate and untested application of tables developed under different ecological environments.

OBJECTIVE

The objective of this project was to examine the utility of operational herbicide applications as a starting point for the creation of herbicide efficacy tables for species of concern in the region.

METHOD

Candidate areas were selected from operational records, and were ranked for assessment, with the objective of assessing all species/treatment combinations, while ensuring that the species/treatment combinations that occurred more frequently were assessed more frequently.

After stratification, based on ecology, topography, application rate and method, a systematic randomly originating survey of 20 plots (r = 4 m) was conducted. Four woody species were selected for assessment in each survey, with the individual of that species closest to the plot centre being assessed for percentage efficacy. In this survey, 100 percent efficacy was interpreted as complete mortality of the aerial portion of the plant. The assessment was based on impact, one growing season after treatment.

RESULTS

In all, 27 strata were assessed, 21 of which had been treated with glyphosate, 4 with hexazinone (liquid) and 1 each with 2,4-D (ester) and asulam. The species assessed varied with stratum.

Analysis of the results was limited to the calculation of mean efficacy for each species, by stratum. Further analysis was hindered by coefficients of variation that ranged as high as 1.27 and by lack of replication between strata. Percent average efficacy for each application rate was then calculated by species.

DISCUSSION

Only two treatments permitted an examination of trends between application rates. These were glyphosate applied at 5 and 6 L/ha and hexazinone applied at 11.1, 18.9, 22.2, and 37.9 L/ha. For the glyphosate applications, efficacy was examined on: *Alnus viridis* (Sitka alder), *Rubus idaeus* (red

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[1] The field portion of this project was funded by the 1985-1990 Canada-British Columbia Forest Resource Agreement.

raspberry), *Rubus parviflorus* (thimbleberry), and *Vaccinium membranaceum* (black huckleberry). Of those species, only alder appeared to respond to the higher dosage. Huckleberry appeared to be the least sensitive to glyphosate, and to hexazinone.

Significant interpretational problems were encountered with species with strong perennial root systems like raspberry and thimbleberry. The survey assessed damage to only the aerial portions of the plant. Frequent instances of apparent reinvasion by these species were observed in locations previously occupied by species such as fireweed or bracken. It appears that although above ground impact was relatively good, below ground impact was low, the result being an apparently well distributed, healthy source for reinvasion.

These assessments indicate that a shift in the species composition is occurring. After the first year there has been a reduction in the overall vegetation levels, but the exploitation by raspberry of the ecological voids created by more heavily impacted bracken and fireweed may indicate the nature of the species shift created by herbicide treatment.

The magnitude and direction of the species shift are speculation. It is conceivable that the vegetation reduction may be brief, and that the resultant complex will provide an even less favourable environment to tree growth, with the only benefit to tree performance associated with the short void between the reduction of the first complex and the dominance of the second. Quantification of the shift can only be achieved by permanent pre- and post-treatment plots, together with control plots to separate successional from treatment-induced change.

CONCLUSIONS

If the limitations of the procedure are acknowledged, operational applications of herbicide can by used as the basis for assessing short-term above ground impacts of herbicides for woody species of concern.

Given these limitations, a first approximation efficacy table was developed using data from this project and from other projects in the region.

Interspecific Competition Indices for Vegetation Management Decisions in Young Douglas-fir Stands

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Decreasing budgets for vegetation management in many regions and rising concern over the use of some control methods has increased the need for more objective approaches to making treatment decisions in young forest plantations. A major limitation to accurately evaluating and justifying treatment prescriptions, has been a lack of operational techniques to link a measurement of competing vegetation to potential tree survival and growth.

Quantitatively isolating the effects of interspecific competition in forest stands is a challenging task. Long periods of time generally are required and it is often experimentally difficult to remove the confounding influence of other factors that affect tree survival and growth. Further, conventional approaches of measuring plant density, which have been used to evaluate the effects of intraspecific competition or stand density, are not generally applicable to quantifying interspecific competition in young forest stands. Trees in young plantations generally are surrounded by plants of various species, growth forms, ages, origins, densities, proportions and spatial arrangements that change through time. Identifying the vegetation parameters that can most accurately predict tree survival and growth is necessary to develop quantitative techniques for evaluating forest vegetation management options.

Two existing site-preparation experiments, located on the Siuslaw National Forest in the Oregon Coast Range, were used to develop:

1. an efficient and meaningful method of quantifying woody vegetation in plantation examinations; and
2. mathematical models that describe the influence of woody vegetation on the size of Douglas-fir saplings.

Nearly 800 trees on 9 study sites were used to develop a set of regression equations describing the effects of woody vegetation, and other factors in the reforestation environment, on the size of 4- to 9-year-old Douglas-fir saplings. The final equations describe the relation of tree age, interspecific competition from woody vegetation, first-year height, animal damage, prescribed burning, slope aspect and slope angle to the height, stem diameter, stem volume and crown volume of individual trees.

Twenty-three indices of interspecific competition from surrounding woody vegetation, calculated from extensive and intensive vegetation measurements around individual trees, were evaluated. Nearly all indices were negatively correlated with tree size. The index that gave the most precise estimate of interspecific competitive effects on stem diameter, stem volume and crown volume, was a visual estimate of woody vegetation cover that was equal or taller than 66% of tree height. Woody vegetation cover that was equal or taller than 125% of tree height was the most precise index for predicting total tree height. Ignoring woody vegetation below 66 and 125% relative tree height apparently improved the index by removing woody vegetation that was equivalent to herbaceous vegetation. The competition index also interacted significantly with tree age, indicating that the negative effect of woody vegetation on tree size increased with time.

The size of individual Douglas-fir trees, through the ninth year after planting, was positively correlated with their first-year height. According to the equations, differences in first-year height among individual trees increased with time; thus, assessment of first-year height in new plantations can be an indicator of future tree performance.

A subjective ranking of recent browsing and clipping of stems and foliage by animals was negatively correlated with Douglas-fir size. Tree height was reduced 24% relative to undamaged trees when light or moderately damaged, and 54% when heavily damaged. Tree height and crown volume were reduced more by animal damage than was stem diameter or stem volume. Height reduction of 7-year-old trees from

heavy animal damage was equivalent to the influence of 165 percent cover of woody vegetation, or the loss of four-years growth.

Prescribed burning for site preparation was positively correlated with tree size. Tree height and stem diameter increased 11 and 17%, respectively, by prescribed burning. While burned plots had 15% less woody vegetation cover than unburned plots, the positive effect of fire in the regression models was independent of the competition index. The possible cause for a beneficial effect of prescribed burning on tree size could not be determined in this study.

Total height, stem diameter and stem volume also were significantly influenced by the topographic position of a tree. When other factors were held constant, trees on southeast aspects were larger than trees on other aspects. The sine and cosine functions, which describe the effect of slope and aspect, indicate that tree performance was positively correlated with solar radiation loads on Coast Range slopes.

The final regression equations provide a means to quantitatively assess the potential influence and relative importance of various factors in the management of young Douglas-fir plantations. The equations also provide a set of working hypotheses that will be tested and refined in additional studies.

Effects of Vegetation and Soil Profile on Planted White Spruce Seedlings[1]

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INTRODUCTION

In interior Alaska near Fairbanks, the mean annual temperature is -3°C. In this cold climate, white spruce (*Picea glauca* (Moench.) Voss) grows well only on sites with relatively warm soils, such as young flood-plain terraces where permafrost has not yet developed. Flood-plain soils are composed of an organic layer ranging from a few centimeters to over a meter thick, depending on the age of the site. This is underlain by mineral soil and gravel. The overall organic layer is interspersed with thin bands of silt deposited during flood, creating buried organic horizons. During the course of flood-plain succession, soil temperatures steadily decrease as the insulating organic layer develops.

Management techniques needed for successful regeneration of flood-plain sites are, as yet, not well understood. This summary describes preliminary results of the first large-scale study of white spruce regeneration on these flood-plain sites.

METHODS

The study area was on Willow Island, a 210-ha island in the Tanana River, 32 km southwest of Fairbanks, Alaska. The island consists of three terraces, which differ in age, vegetation, thickness of the organic layer and soil temperature. Site 1 occurs on the oldest river terrace and has a thick organic layer and cold soil temperatures. It is completely underlain by permafrost with a seasonally active thaw zone of 37 to 70 cm. Site 3 occurs on the youngest of the three terraces. It has little organic layer development and warmer soils. Site 2 is intermediate with scattered pockets of permafrost.

Portions of each site were clearcut during winter 1983. (Other areas were shelterwood cut, but those data will not be considered here.) Mechanical scarification with either a Bracke-type patch scarifier (mention of product name in no way implies endorsement by the U.S. Department of Agriculture) or a skidder-mounted blade was completed that summer. In addition, part of Site 1 received a broadcast burn. Burned, scarified and control areas were planted with 1+0 containerized white spruce seedlings in June 1984. Twenty seedlings from each site preparation area were randomly selected; for each seedling, the soil profile was described to a depth of 20 cm. The mean organic component of the profiles in each treatment type was computed. Visual estimates were made of the percent cover of competing vegetation in a 0.5 m^2 area around each seedling in July 1985. Seedlings were measured at the end of the 1985, 1986 and 1987 growing seasons.

After simple correlation analysis, site and treatment means were subjected to a series of ANOVAs and Scheffé's tests ($p<0.05$) to compare means.

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[1] *This work was supported by the Division of Forestry, Alaska Department of Natural Resources, and by the USDA Forest Service, Pacific Northwest Research Station. The senior author extends her appreciation to those agencies.*

RESULTS

Effective removal of the organic layer by mechanical scarification depended primarily on initial thickness of the layer. On Site 1, where initial organic accumulation was thick and numerous small stumps impeded the equipment, scarification removed little of the profile. The organic component of the profile did not differ between scarified areas and unscarified control areas. High-intensity broadcast burning on Site 1, however, caused a significant reduction of the organic component of the soil profile. On Sites 2 and 3, where the initial organic layer was thinner, scarification significantly reduced the profile organic component.

Scarification had little or no effect on the 1985 total percent cover of competing vegetation on any of the three sites. High-intensity broadcast burning significantly reduced percent cover of competing vegetation.

Seedling growth (height increment over three years, diameter increment over two years, and leader internodal bud production for 1987) was correlated with reduction of the organic profile component and with warm soil temperatures. On Site 1, seedling growth was no different among the scarified and control areas. On Site 2, growth was better on scarified areas than on controls, but there was no difference between the two scarification methods. On Site 3, seedlings in bladed areas grew more than those in patched areas, and those in patched areas grew more than those in control areas. Seedlings in the high-intensity burn of Site 1 grew about the same as those in the bladed area of Site 3. Soil temperatures increased significantly in the burned areas, about three times the increase that occurred in clearcut, unscarified areas (Dyrness *et al.*, in press).

DISCUSSION

Results suggest that temperature and soil profile characteristics are more important than competition in determining seedling growth during the first years after planting. On all sites, seedling growth was highest following a significant reduction of the organic layer.

The positive correlation between seedling growth and the high-intensity burn area on Site 1 suggests that, at least in the short-term, cold, unproductive flood-plain sites can be converted to productive sites by methods that remove most of the organic soil layer. The long-term effects of these treatments on site productivity are still unknown.

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POSTERS

VEGETATION COMPETITION AND RESPONSES: EXPERIMENTAL RESULTS

The Impact of Non-coniferous Vegetation on the Performance of Engelmann Spruce (*Picea engelmannii* Parry) Seedlings on Subalpine Forest Cutovers in Southern B.C.

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INTRODUCTION

The forests of the Engelmann Spruce-Subalpine Fir (ESSF) Zone are an important timber resource in B.C. However, sites do not return quickly to timber production after harvesting because of the slow regeneration of spruce and fir at high elevations. Planting of Engelmann spruce is widely practiced, but the early performance of planted seedlings is generally poor. Non-crop vegetation may be important in reducing performance but little is known about the relative importance of this factor in spruce regeneration. This research is directed at determining the impact of non-coniferous vegetation on the early growth and survival of Engelmann spruce within subalpine communities.

Vegetation on many cutovers in the ESSFm subzone is dominated by one or both of two major species complexes, an ericaceous shrub complex characterized by *Menziesia ferruginea* (false azalea) and *Rhododendron albiflorum* (white-flowered rhododendron), and a perennial herb complex dominated by *Valeriana sitchensis* (Sitka valerian) (Figure 1). The two complexes are also characteristic of the ESSFm forest understory.

FIGURE 1. A cutover in the ESSFm which was logged in the winter of 1983 to a diameter limit of 8" illustrates the mixed herb and shrub vegetation typical of young NSR sites in the subalpine zone.

The specific objectives of this study developed from the general hypothesis that significant differences exist between herb and shrub complexes as competitive environments for seedling growth. These differences may have important implications for the selection of stocktypes, planting times and locations, and site preparation to improve regeneration success in the ESSFm.

The study objectives are to:

1. describe and compare the edaphic, microclimatic and community characteristics of the herb and shrub complexes, on cutovers and in the mature spruce-fir forest;
2. compare the survival and growth of Engelmann spruce seedlings, with and without the presence of above-ground vegetation, within and between the herb and shrub complexes;
3. compare the growth and survival of naturally established seedlings and different stocktypes of Engelmann spruce within and between the herb and shrub complexes; and
4. determine whether species of the herb complex replace those of the shrub complex in response to removal of above-ground, or above- and below-ground vegetation, on cutovers and in the mature spruce-fir forests.

METHODS

Several descriptive and manipulative experiments were designed to address the research objectives. Two young cutovers and a mature forest stand in the ESSFm, near Vavenby, B.C., were selected as study sites. A climate station was set up on one cutover to record precipitation, solar irradiance, relative humidity and air and soil temperatures, in both complexes, throughout the study. To describe the two complexes (Objective 1), community composition and structure, biomass and litterfall, light, and soil physical and chemical properties were measured in plots on all sites.

Objectives 2 and 3 were addressed by planting seedlings of two Engelmann spruce stocktypes (a cold-stored stock which flushed soon after planting and a hot-lifted stock which did not flush the year of planting) into both complexes in plots where above-ground vegetation was either removed or left undisturbed (Figure 2). Twice during the growing season measurements were made of several seedling growth parameters, soil temperature and moisture, and light levels. Litter and resin bags were buried to compare rates of decomposition and nitrogen ion movement among treatments.

FIGURE 2. A plot in the shrub complex on a NSR cutover in the ESSFm in which two Engelmann spruce stocktypes were planted after removal of above-ground vegetation.

To address Objective 4, plots within the herb and shrub complexes were subjected to three levels of disturbance on all sites. Above-ground vegetation was removed by clipping, and above- and below-ground vegetation was removed by screefing, or vegetation was left undisturbed. Pre- and post-treatment measurements of distribution, cover and structure of plant populations were used to determine whether shifts in species dominance occurred among treatments or vegetation types.

FIRST SEASON RESULTS

Soil temperatures differed markedly between the herb and shrub complexes (Objective 1). Temperatures at 5 cm ranged between 6°C and 18°C and followed a similar trend in both complexes, but were lower in the herb complex during July and August. In the herb complex, soil temperatures at 20 cm began to rise in early July and reached a maximum daily average in mid-August of 15°C. Shrub temperatures rose little, peaking at 10°C in late July and remaining 5°C lower than herb values up to the last measurement date. Minimum temperatures at 20 cm were near 6°C.

An analysis of covariance indicated no statistically significant differences in first season height growth of cold-stored stock (Objectives 2 and 3) among any of the treatments. The average height of seedlings in August was 20 cm, but variation among individuals in initial size was large. Seedlings in plots where vegetation was removed flushed and formed buds earlier, and were sturdier than seedlings under vegetation. The latter, however, were greener and did not show the chlorosis commonly observed in the open-grown seedlings.

There were large differences between the herb and shrub complexes in vegetation development (Objective 4) two months after clipping. Within the herb complex, vegetative regrowth by dominant species was vigorous, but reproductive structures were not replaced. Regrowth after clipping was poor in the shrub plots and was mostly by herbaceous perennials. Recruitment from seed was not detected this year. There was little recovery of vegetation on any of the screefed plots, or on clipped plots in the forest, this season.

Effects of Shrubs and Herbs on Conifer Regeneration and Microclimate in the *Rhododendron-Vaccinium-Menziesia* Community of South-Central British Columbia

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A field study was established to determine the impact of interfering vegetation on survival and growth of Engelmann spruce (*Picea engelmannii* Parry) and lodgepole pine (*Pinus contorta* var. *contorta* Dougl.) at a site in the ESSF Zone of south-central B.C. The study examined:

1. the influence of varying amounts of shrubs and herbs on microclimate and planted seedling performance;
2. relationships between various measures of vegetation interference and conifer seedling growth; and
3. the response of six major shrub and herb species to manual cutting and mechanical scarification.

After two growing seasons, survival of both conifers was greater than 97 %, except in the presence of the highest levels of interfering vegetation, where survival was 82 to 84%. Seedling diameter showed the strongest correlation to levels of interference. In the absence of interfering vegetation, mean diameters of spruce and pine were 21.3 and 27.5% greater, respectively, than mean diameters of seedlings in the undisturbed vegetation. Height growth generally did not respond to interference levels. Soil water potential was never lower than -0.01 MPa and was the same at all levels of interference throughout the growing season. Mid-day and pre-dawn spruce xylem water potential also did not vary because of vegetation removal treatment. Even though soil water was ample, moderate water stress was observed, most likely because of restricted uptake caused by cold soil temperatures. Light levels under undisturbed vegetation were sufficiently low to impair photosynthesis. Results suggest that low soil and air temperatures, and low light levels, may be the most important primary factors inhibiting conifer seedling performance beneath the undisturbed brush community.

The relationship between growth of individual spruce and pine and various measures of vegetation interference was always negative. Measure of percent vegetation cover were consistently the best predictors of seedling growth. A maximum of 25% of the variation in seedling growth was explained by measures of interference. The response of conifer seedlings to interference may be nonlinear, with a decreasing response observed at high amounts of interference. However, more than two growing seasons may be required for the shape of the response curve or model to become clear in the slow-growing ESSF environment. Large variance in seedling growth at low levels of interference suggests either that microsite variability or genotype differences constrain seedling performance, even in the absence of interference.

Recovery of the four dominant shrubs, white-flowered rhododendron (*Rhododendron albiflorum* Hook.), black huckleberry (*Vaccinium membranaceum* Dougl.) oval-leaved blueberry (*V. ovalifolium* Smith), and false azalea (*Menziesia ferruginea* Smith.) following manual cutting was slow. (Figure 1 and 2) After two growing seasons, the height of the tallest stems averaged 10 to 15 cm (or about 10-30% of precut levels), and had not overtopped the conifers. Shrub vigor appeared unaffected by one additional cutting. The two major herb species, Sitka valerian (*Valeriana sitchensis* Bong.) and Indian hellebore (*Veratrum viride* Ait.) had recovered to precut levels by early in the second growing season. Sitka valerian vigor decreased after multiple cutting. Mechanical scarification either severely damaged or completely killed the shrub species. Herb species responded to mechanical scarification as they did to manual cutting.

FIGURE 1. Treatment plot with complete shrub and herb removal.

FIGURE 2. Recovery of white-flowered rhododendron 1 year after manual cutting.

Germination, Survival and Early Growth of Red Alder Seedlings in the Central Coast Range of Oregon

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The effects of forest disturbance and soil moisture levels on seed germination, survival and early growth of red alder (*Alnus rubra* Bong.) seedlings was studied over two growing seasons at four sites representing a climatic gradient within the central Coast Range of Oregon. The study showed that detailed examination of ecological factors controlling each stage of the regeneration cycle can help to explain patterns of red alder abundance within the Coast Range landscape.

Exposure of mineral soil and spring rainfall patterns were the most important factors affecting seed germination. In general, there was no difference in seedling emergence on recent clearcuts and adjacent unlogged forests, but emergence was much higher on disturbed mineral soil seedbeds than on undisturbed organic seedbeds. On both types of seedbed, emergence was positively correlated with spring soil moisture conditions ($r^2 = 0.60$). However, on undisturbed seedbeds, seeds were more prone to drying out, were subject to heavier losses from invertebrates and pathogens, and germination was inhibited by light conditions beneath vegetation and litter layers.

Patterns of seedling survival differed greatly between clearcut sites and adjacent unlogged forest. In the forest, seedlings had poor vigor and quickly succumbed to pathogens, herbivores and rain splash. In clearcuts, survival was better. Heat and drought injury were the primary causes of first-year seedling mortality, while interference from surrounding vegetation was most important in the second year. Exposure of mineral soil did not enhance seedling survival unless the soil was also compacted. Seedlings on compacted skid roads were less affected by heat and drought injury in the first year and experienced less interference from surrounding vegetation in the second year. Mean survival reflected natural patterns of red alder abundance in the Coast Range and was strongly correlated with minimum summer soil moisture levels ($r^2 = 0.70$).

Growth of seedlings on clearcuts was much slower than rates typically described for red alder in the literature. Mean height of 1-yr seedlings was just 2.1 cm. By the end of the second growing season, mean heights ranged from 3.1 to 33.2 cm (overall mean 12.1 cm) and most seedlings were still well below the height of associated shrubs and herbs (Figure 1).

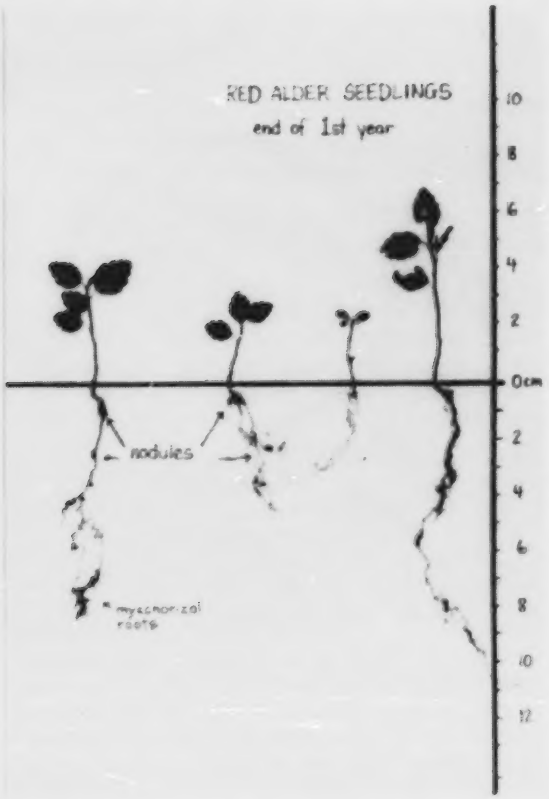

FIGURE 1. Typical red alder seedlings at the end of the first growing season (2-6 cm in height)

OPERATIONAL IMPLICATIONS

A flush of seed germination can be expected in the first spring following logging of stands containing red alder, but relatively little emergence from buried seed will occur in subsequent years. Site preparation treatments should be planned to take advantage of this phenomenon. Exposure of mineral soil increases alder seed germination and deep disturbance such as that associated with skid roads and landings may enhance seedling survival and growth. However, in very moist, humid environments, alder will germinate and survive well even if no soil disturbance occurs. Abundant alder establishment can be expected in years with moist to wet spring weather and scattered rain showers during the summer months. Because growth of young alder can be very slow, seedlings may not become visible to operational foresters until 3-4 years after clearcutting.

Response of Vegetation to Burning in the Sub-Boreal Spruce Zone

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INTRODUCTION

In the Sub-Boreal Spruce (SBS) Zone prescribed burning is used on over half of the area harvested to prepare sites for planting and reduce fire hazard. The steep, rough terrain and unstable soils typical of many sites in the SBS restrict the use of other site preparation treatments. Burning is often more cost effective than other site preparation treatments and is therefore used most often. In the Prince George Forest Region much of the future harvesting is scheduled for the wetter SBS subzones and opportunities for cost savings by determining the most effective site preparation treatments for these brush prone sites are considerable.

Ecosystem-specific information on the rates and patterns of vegetation development after different burning prescriptions and the impacts of vegetation on crop trees is needed to facilitate:

1. assessment of suitability of burning on different sites;
2. determination of optimal burning prescription;
3. prediction of need for and scheduling of vegetation control after burning;
4. scheduling of free-growing surveys; and
5. selection of appropriate stock.

RESPONSE OF VEGETATION TO BURNING IN THE SBS ZONE

Vegetation Regrowth Rates and Patterns

Vegetation development patterns in different ecosystems are determined by burning severity, which influences the degree of resprouting and establishment success of off-site seeds. Vegetation on the drier sites in the SBS may be killed by severe burns, however, only short-term reduction in the vegetation cover occur on subhygric sites (Hamilton and Yearsley 1987).

The overall rate of regrowth of most shrubs and herbs was generally fastest in the subhygric Devil's club sites and slowest in the submesic Queen's club sites (Figure 1). However, where aspen had been present before harvesting, often the case in submesic sites, rapid vegetation regrowth of aspen suckers was evident soon after burning.

In submesic sites, shrubby and herbaceous vegetation often grew to a height of about 75 cm by five years after burning. Where aspen was common before burning, suckering will occur and sprouts can grow to over a meter by one year after burning. In subhygric sites vegetation will often reach a height of about 1 to 1.5 m by five years after burning.

Vegetation in submesic sites will reach 100% cover by about 3-4 years after burning, while in subhygric sites complete vegetation cover can develop within one to two years after burning (Figure 1).

The lodgepole pine seedlings that are planted in submesic sites will generally outgrow most other vegetation, except aspen and other hardwood trees. In subhygric sites, shrubs and herbs will generally overtop spruce within a few years after burning and often continue to shade the seedlings for five years or more.

Relationship Between Burning Severity and Vegetation Development One Year After Burning

The average depth of burn was 5.3 cm on the three submesic sites that were monitored and 3.0 cm on the three subhygric sites. An assessment of the amount (volume) of vegetation on the sites indicated that there was three times as much vegetation on subhygric sites compared with submesic sites one year after burning (Figure 2). Vegetation cover was 28% on submesic sites and 60% on subhygric sites, and average vegetation height was greater on the wetter sites (Figure 3).

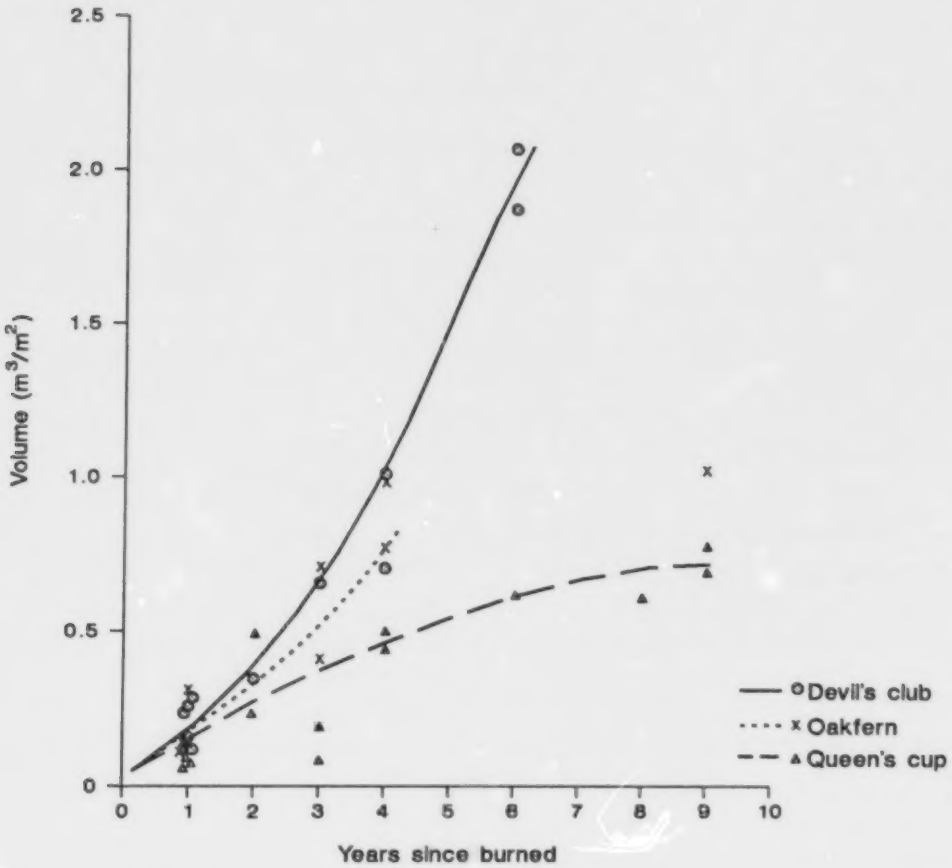

FIGURE 1 Vegetation development in three ecosystems in the SBS Zone.

Response to Burning of Key Species

Burning promotes the sprouting of fireweed from rhizomes and the establishment from seeds. Fireweed will dominate most sites for the first 10 years until overtopped by conifers or other taller vegetation. Burning also stimulates the germination of seed-banking species including elderberry and red raspberry. Thimbleberry resprouts and establishes from buried seed immediately after burning and is common in most sites. Other species including black huckleberry and black twinberry are less tolerant of burning and slower to regrow. Birch resprouts from root crowns and seeds-in over time.

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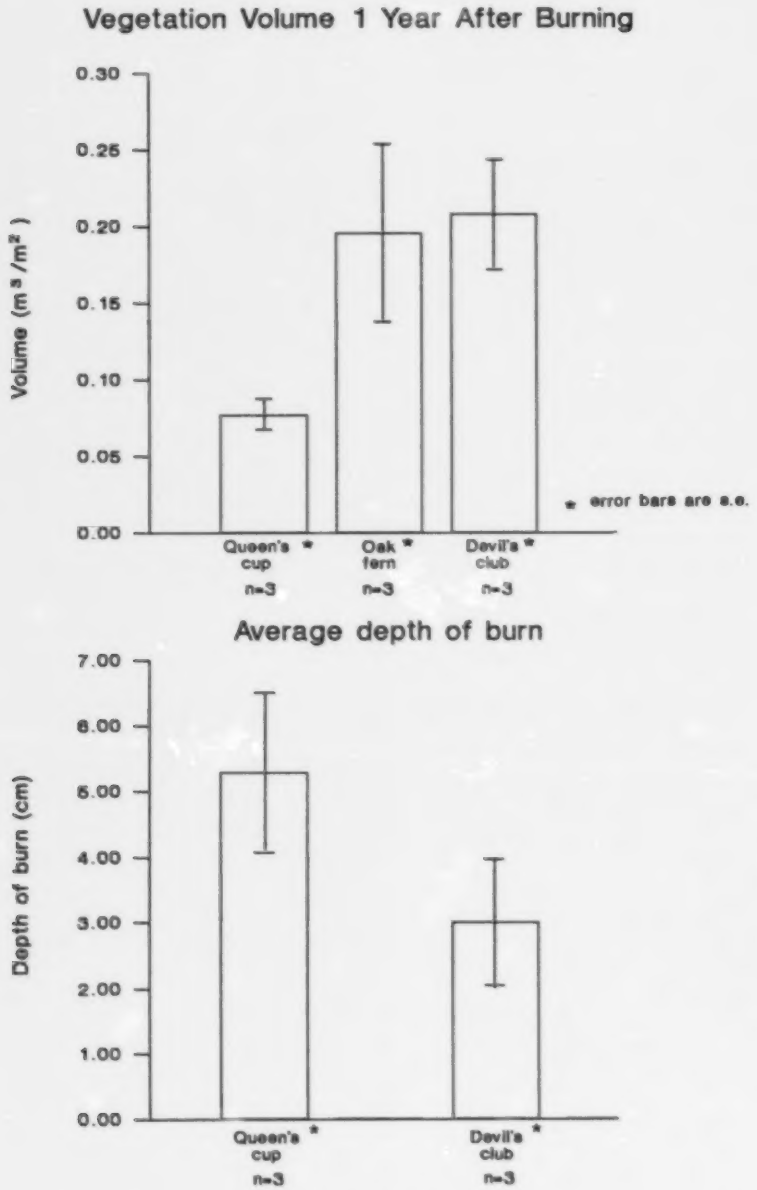

FIGURE 2 Average depth of burn and vegetation volume one year after burning in the SBS Zone.

Queen's cup site 1 year after burn

Queen's cup site 4 years after burn

Devil's club site 1 year after burn

Devil's club site 3 years after burn

FIGURE 3. Vegetation development after burning in two site types in the SBS.

An Evaluation of the Clearing Saw for Brushing Shrub Dominated Plantations in the ICH

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On moist sites in the Interior Cedar Hemlock Zone, early plantation survival and growth are often compromised by physical damage or competitive stress from shrubs and forbs. If long term timber management goals are to be met on these sites, early vegetation control treatments, which are both silviculturally effective, and within acceptable cost limits, must be identified and implemented.

A study to determine the cost-effectiveness of clearing saw treatments in shrub dominated plantations, funded under the Federal Component of the Canada/B.C. FRDA, was established near Nelson, B.C. on a site in the ICHa3. Plots were located in areas burned for site preparation in 1984 and 1985. In phase 1, completed in 1987, cost, productivity and accidental crop damage at time of treatment were determined, and the productivity of three clearing saw blade types were compared.

Time and motion measurements were taken on 54 treatment units (16.7 m x 25 m). As productivity is a function of site conditions, treatment units were equally represented in 3 blocks established to account for slight differences in vegetation, terrain and slash condition. Well trained operators were asked to cut all non-crop vegetation as low to the ground as practical.

Averaged over all blocks, and blade types, productivity was 0.025 ha/productive hour (range 0.023 to 0.030). Extrapolation to an 8-hr. man-day with 80% utilization of time gives an average of 6.3 man-days/ha (range 5.9 to 6.8).

Average treatment cost was $775/ha (range $604/ha to $804/ha), based on saw and operator costs of $15.40/hour.

Significantly higher productivity during actual clearing time, was obtained with the MULTI 300 blade (0.043 ha/hr); however, neither the MULTI 300 nor MULTI 255-4 was suitable for cutting woody stems over 2 cm in diameter. Although the MAXI 200 was slower overall (0.031 ha/hr), it was the only blade suited for larger woody stems.

Nearly 1 in 5 of the 308 crop trees assessed (19.4%) had damage attributed to treatment. Frequency of direct saw injury is related to visibility of the tree within the shrub complex; less damage was noted among trees with projecting leaders. The longer term impact of damage noted at time of treatment remains to be assessed.

In phase 2, growth responses of crop seedlings and major competing brush species will be evaluated over a 5-year post-treatment period on the same site. Comparisons will be made between untreated plots, plots brushed only once, and plots brushed on an annual basis.

An Overview of Vegetation Problems in the ICHm2 and ICHb Subzones of the Southern Interior

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Systematic field sampling of a large number of logged openings was undertaken to provide comprehensive documentation of backlog regeneration problems in the Interior Cedar Hemlock (ICH) Zone. Forty-five sites in the Wet ICH subzone (ICHb) in the Revelstoke Forest District and sixty-six sites in the Moist Central ICH subzone (ICHm2) in the Vernon and Salmon Arm districts were visited. The objectives were to summarize past regeneration success for all operationally important silvicultural treatments, to summarize factors that led to regeneration success and failure, and to summarize obstacles to regenerating unsuccessful treatments. Since vegetation is one of the factors affecting regeneration success and hampering successful regeneration of backlog sites, vegetation data were collected at each field site. This provided an overview of vegetation problems in the ICHb and ICHm2 subzones.

Vegetation data were collected for submesic, mesic and subhygric sites that were last disturbed (burned, mechanically site prepared or logged with no site preparation) between 1960 and 1982. The percent cover and height of all vegetation species with at least five percent cover were recorded at each site.

The majority of ICHb sites that were disturbed between 1960 and 1982 are heavily vegetated. Vegetation problems are most pronounced on sites that are mesic and wetter, in the climatically wettest areas, and that received minimal ground disturbance. Herbaceous and shrubby vegetation generally are more important than hardwood trees in contributing to regeneration failure and in hampering successful regeneration of backlog sites.

Fireweed (*Epilobium angustifolium*) is the dominant species on mesic and subhygric ICHb blocks, especially those that were burned or mechanically site prepared. Many sites, particularly those that were not site prepared, have considerable amounts of other species, especially thimbleberry (*Rubus parviflorus*), raspberry (*Rubus idaeus*) and lady fern (*Athyrium filix femina*). Five or more years after disturbance the total cover of herbaceous and shrubby vegetation is often 90 to 100% and the height is typically 1 to 1.7 m. Vegetation tends to be lighter on areas that received moderate to high impact burns or mechanical site preparation than on areas that were not site prepared.

Vegetation is considerably lighter on drier (submesic) ICHb sites than on the wetter sites. Broadcast burning has been a common treatment on submesic ICHb sites. It results in light to moderate vegetative cover dominated by fireweed and falsebox (*Paxistima myrsinites*).

Birch (*Betula papyrifera*) is the main hardwood species found on ICHb sites. It is not a widespread problem. There is typically less than ten percent cover of birch ten years after disturbance. Birch is, however, a problem on some sites. Birch should be recognized as a threat to growth of some older plantations and as an obstacle to regeneration of some backlog sites. Other hardwoods that occur on logged sites in the ICHb subzone are mountain alder (*Alnus incana*), trembling aspen (*Populus tremuloides*), cottonwood (*Populus balsamifera*) and willow (*Salix sp.*). They do not pose extensive problems for regeneration.

Vegetation on logged sites in the ICHm2 subzone is considerably lighter than in the wetter ICHb subzone. Most logging in the ICHm2 subzone has been done on submesic and mesic sites and burning and mechanical site preparation have been common. Regardless of treatment, herbaceous and shrubby vegetation generally do not form the dense cover that is found on mesic ICHb sites. Fireweed is the dominant species on submesic and mesic ICHm2 sites. Thimbleberry, raspberry, bracken fern (*Pteridium aquilinum*) and falsebox are the other main species.

Birch occurs extensively on logged sites in the ICHm2 subzone. It is mainly a problem on mechanically disturbed sites where it can reach 50 to 100 % cover 5 to 10 years after disturbance. Birch usually does not pose problems for regeneration establishment but may affect the growth and survival of trees several years after they are established. A limited number of sites that were not successfully regenerated in the past are now occupied with thick birch. Trembling aspen, cottonwood and willow occur on many logged sites in the ICHm2 subzone but they do not pose widespread problems for growth or survival of conifers or for regeneration of backlog areas.

Root Distribution and Biomass of Competing Vegetation on Two Recently Burned Sites in the CWHb Subzone

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INTRODUCTION

On the northern part of Vancouver Island, in the CWHb subzone, most Sitka spruce (*Picea sitchensis*, Bong. Carr.), western hemlock (*Tsuga heterophylla*, Raf. Sarg.) and western redcedar (*Thuja plicata*, Donn) plantations experience reduced growth or check 6 to 8 years after planting. Associated with this is the complete invasion of the plantations by competing vegetation, especially salal (*Gaultheria shallon*, Pursh), (Figure 1). Light competition does not explain this growth reduction because, at this time, the trees are above the salal.

One current and plausible hypothesis for this reduced growth is that salal competes for nutrients or inhibits the availability of nutrients to seedlings (Germain, 1985). Another hypothesis suggests that the burning of these sites induces a flush of nutrients (or "assart effect") that explains the initial 6 to 8 years of good growth, but after which, these sites become inherently nutrient deficient.

The objectives of this study are:

1. to quantify root distribution and biomass of competing vegetation, especially salal, in an 8-year post-burning site as a preliminary step in testing one of the two hypotheses stated above; and
2. to examine the recovery of the below-ground biomass early after burning using two sites (2- and 8-year post-burning).

Figure 1. Salal reinvasion of a cutover 8 years after burning in the CH forest type (sites originating from undisturbed old-growth western redcedar-western hemlock stands). Coniferous seedlings experience stagnation on these sites.

METHODOLOGY

Ten root cores (1935 cm^3) were taken randomly from four cutovers, two of them burned 2 years ago and the other two burned 8 years ago. Each core was separated into subcores according to depth: 0-15, 15-30 and 30-45 cm. For each subcore, live roots were sorted into different sizes (0-1, 1-2, 2-5 and >5 mm) and species groups (Salal-Vaccinium and Bunchberry-Fireweed, Figure 2). The roots were then dried at 70°C for 24 hrs and weighed to determine the oven-dry biomass per hectare (kg/ha). The above-ground oven-dry biomass of the competing vegetation was also assessed using 1 m^2 plots.

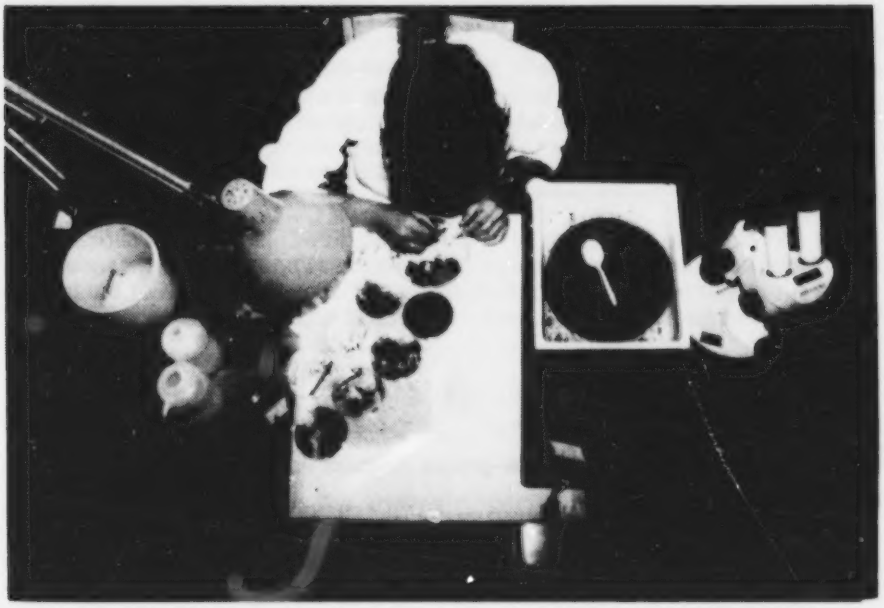

Figure 2. Assessment of the root biomass of competing vegetation, especially salal, in the laboratory. Salal roots are thought to compete for nutrients and/or to exudate chemicals that inhibit nutrient uptake and availability to trees.

RESULTS

There were 2130 kg/ha of oven-dry live root biomass (all sizes) in the 2-year post-burning site, of which 1690 kg/ha were live fine-root (<2 mm). The Salal-Vaccinium group (of which salal was the dominant species) comprised 95% of the live fine-root biomass. Although the above-ground vegetation was very sporadic 2 years after burning, live roots were found in all core samples at every depth. There were 11 980 kg/ha of oven-dry live root biomass (all sizes) in the 8-year post-burning site, of which 5560 kg/ha were live fine-roots. On this site, the Salal-Vaccinium group made up 75% of the live fine-roots, salal being the dominant species. The shoot:root ratio of the competing vegetation in the 2-year post-burning site was 0.62, whereas in the 8-year post burning site it was 0.40. The lower ratio in the 8-year post-burning site was due to the high amount of live rhizome (roots > 2 mm) present. The proportion of live rhizome to total root was greater 8 years after burning (54%) than 2 years after burning (21%).

DISCUSSION

Findings showed that there was already a significant amount of roots 2 years after burning. Moreover, competing vegetation, especially salal, appears to direct proportionally more energy into rhizome development as it ages.

The high amount of live fine-roots found in the 8-year post-burning site is similar to that found by Vogt *et al.* (1987) in a low-productivity (class IV) 11-year-old stand of Douglas-fir dominated by competing vegetation (5780 kg/ha). However, this is greater than the amount found in many older forest stands (Vogt *et al.*, 1987: Keyes and Grier, 1981). This seems to indicate that 8 years after burning, the competing vegetation dominated by salal fully occupies the below-ground environment. This being the case, it can explain the reduced growth of the coniferous seedlings 6 to 8 years after planting; competing vegetation, especially salal, taking up most of the nutrients and/or releasing phytotoxins that inhibit seedling growth. These results constitute fundamental information for the ongoing research on the salal-coniferous seedling interactions in the CWHb subzone.

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Increasing Seedling Growth on Salal Sites Using Controlled-release Fertilizer

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The effect of Osmocote®, 17-7-12 controlled-release fertilizer applied to western hemlock (*Tsuga heterophylla* (Raf.) Sarg.) seedlings at the time of planting was quantified in a study established approximately 20 km northeast of Port Hardy, B.C., in the Outer Very Wet Hypermaritime Coastal Western Hemlock variant. The aspect of the study site ranges between southwest and southeast with slopes of 20 to 35%. A residuohumimor humus form lies on an Orthic Ferro-Humic Podzol which has a loamy sand texture. The soil moisture and soil nutrient regimes are moist and poor, respectively. Broadcast burning followed logging on the site in which this experiment was carried out. In addition, planting spots were created over the experimental area with a brush rake on a backhoe.

The experiment consisted of 5 treatments and a control. These were allocated randomly among 12 plots each containing 53 planted 1+0 western hemlock. Each of the treatments and the control occupied 2 plots. The five treatments were:

1. 29.4 g Osmocote® applied in a dibble hole 7.5 cm upslope from the seedling;
2. 29.4 g Osmocote® spread on the surface around the seedling in a 15 cm diameter circle;
3. 58.8 g Osmocote® applied in a dibble hole as in 1, above;
4. 58.8 g Osmocote® applied on the surface around the seedling as in 2 above; and
5. 58.8 g Osmocote® combined with dolomite lime, potassium sulfate, and Frit®, 503 (containing micronutrients iron, zinc, manganese, copper, boron and molybdenum), applied in a dibble hole as in 1, above.

Seedling mortality rates, height growth, diameter growth, foliar nutrient concentrations and competition by salal and other species were determined after the first and second growing seasons in the field.

Mortality rates were not significantly (95% confidence level) altered by fertilization. However, mortality rates tended to be lower in the control plots (maximum mean after two growing seasons was 28%) than in the treated plots (maximum mean for a treatment after two growing seasons was 39%).

Fertilization increased western hemlock height growth substantially. The mean height of trees in the control plots after two growing seasons was 37 cm while, for the treatments, the means were from 59 to 73 cm. Diameter growth was also increased dramatically. The mean diameter of trees in the control plots after two growing seasons was 5.9 mm while, for the treatments, the means were from 10.8 to 13.1 mm. The growth differences after two growing seasons in the field between a representative control tree and a fertilized tree are depicted in Figures 1 and 2.

Foliar nitrogen content in fertilized trees was significantly increased above that of control trees after the first growing season. However, there was no statistically significant difference after the second growing season. Phosphorus and potassium contents of foliage were not enhanced by fertilization. Fertilization with NPK did not reduce any other nutrients to levels that were considered to be deficient, that is, no deficiencies were induced.

Three competition indices were used to analyze the data for competing species. The first index was based on the percentage cover of the three major non-crop species around the trees (within 50 cm). There was no statistically significant difference after the second growing season between the control and the treatments nor was there one between the treatments. The second index was based on percentage cover, the height and the minimum and maximum distances and the third index was based on percentage cover and height of the three major non-crop species around the trees. Both of the latter indices were

significantly greater after the second growing season for the 58.8 g broadcast treatment than for the control and other treatments. None of the indices differed significantly at the time of planting of the seedlings.

FIGURE 1 A representative control tree

FIGURE 2 A representative fertilized tree

Salal occurred in 76% of the samples. At planting time it covered a mean of 0.5 to 0.8% of the area of the control and treatments. After the second growing season the mean cover was 5.9% for the control plots and was from 2.0 to 7.5% in the treated plots. The highest cover of salal after the second growing season occurred on the two broadcast treatments, suggesting that there may have been an increase in growth due to fertilization. However, the differences in salal cover between control and treatments and between treatments were not statistically significant.

It is premature to recommend the use of controlled-release fertilizers operationally, although the results of this experiment are very encouraging. Before any operational trials are carried out it will be necessary to investigate:

1. the optimum (in terms of growth and economics) rate and application methods for several types of controlled-release fertilizers which are currently available, (e.g. is there a fertilizer that can be added to the plug before sowing?);
2. the effect on different species growing in different substrates and on different sites, (e.g. will there be a positive effect on nutritionally rich sites?); and
3. the effect on non-crop species.

Competition Between Sitka Alder and Lodgepole Pine in the Montane Spruce Zone

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Sitka alder (*Alnus viridis* ssp. *sinuata*) dominates many backlog lodgepole pine sites in the southern interior of British Columbia. Sitka alder has been shown to benefit crop trees by increasing the nitrogen content of forest soils, but may also suppress conifers by competing for moisture, light or other resources.

An experiment to study competitive interactions between a Sitka alder dominated community and planted lodgepole pine was initiated during the summer of 1987 near Kamloops, B.C. The objective of the study is to investigate the relationships between varying densities of the Sitka alder community, growth of lodgepole pine seedlings, and levels of environmental resources and conditions. The site was selected to represent Sitka alder competition levels common to the Very Dry Montane Spruce (MSc) subzone.

The experiment utilizes a neighborhood approach. Gradients of interspecific competition levels were established by varying the density of Sitka alder shrubs and cover of the herb layer over seven treatments. The treatments were replicated three times on the site. Lodgepole pine seedlings (1+0 PSB 211), were planted at 2.5 m spacing. Seedling response variables being monitored are growth, xylem moisture potential and survival. Environmental conditions (air temperature, soil temperature, precipitation, relative humidity and solar irradiance), are being continuously monitored in three treatments, each of which was selected to represent the extremes of competition levels. Environmental resource (soil moisture, soil nitrogen and light) availability is being monitored over the full range of competition levels.

Survival of lodgepole pine was 90% at the end of the first growing season. There are no significant differences ($p < 0.5$) between treatment means for lodgepole pine growth variables. Competitive effects between lodgepole pine and the brush community are not expected to be significant for at least one more growing season.

As the experiment develops, identification of a critical brush density, at which lodgepole pine performance is optimized, may be identifiable. In addition, by monitoring the changes in environmental resources and conditions over the competition gradient, an understanding of the competition processes that are occurring will be developed. This understanding will aid in the establishment of a causal link between lodgepole pine performance and environmental factors.

The Effect of Glyphosate Treatments on a Mixed Brush Community in the ICHd Subzone (SX 83407)

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OBJECTIVE

This trial was established to assess the effects of two application rates of glyphosate on the growth of planted Douglas-fir seedlings, and on selected species in a mixed brush community in the ICHd subzone.

LOCATION

The study area is located on a zonal site in the moist southern interior cedar-hemlock (cedar-grand fir) subzone, above the Pend d'Orielle River in southeastern British Columbia. The site is on a moderate, well drained, slope with a southeast aspect at an elevation of 1050 m. The opening was created by logging in 1974-75 and was planted with 2+0 Douglas-fir in 1975 and 1976. No site preparation was used.

DESIGN

A randomized block design was used, with each treatment replicated three times. Each treatment unit is 20 X 40 m with 10 m between plots. Within each plot are 20 tree-centred subplots. These subplots (radius 1.95 m) act as the basis for both tree and vegetation assessments.

TREATMENTS

Glyphosate was applied on August 16, 1983 using backpack sprayers, at three rates: 1428 g ai/ha, 1072 g ai/ha and no treatment (control). Application was at the rate of approximately 100 L solution per hectare.

MEASURES

The project was assessed in July 1983, and in September 1984, 1986 and 1987. At each assessment, seedling height, diameter (at 5 cm above root collar) and condition were recorded. Non-tree response was assessed on three target species: *Physocarpus malvaceus* (ninebark), *Symphoricarpos albus* (snowberry) and *Amelanchier alnifolia* (saskatoon). All other species present were grouped into "other herbaceous" and "other woody". A competitive index, based on a formula by Wagner (1982) was used to assess non-tree species abundance:

$$CI = \frac{H \cdot C}{10}\left(\frac{1}{CD} - \frac{1}{FD}\right)$$

where: H = average height (m) of weed species

C = % cover of weed species to nearest 10%

CD = distance (m) from plot centre to closest individual

FD = distance (m) from plot centre to furthest individual (or 1.95 m)

RESULTS

After four years, the height of the seedlings treated at both rates, is greater (but not significantly) than the height in the control. Annual height growths in the fourth year were 45, 32 and 25 cm for the 1428, 1072 g ai/ha, and control treatments respectively (Figure 1).

Similarly, diameters are significantly ($p = .05$) greater for both treatments, when compared with the control. Annual diameter increments in the fourth year were 1.1, 0.9 and 0.5 cm respectively (Figure 2).

There are also 55 and 104% more trees classed as free-growing in the 1428 and 1072 g ai/ha treatments respectively, when compared with the percentage of trees in the same class before treatment. The corresponding value for the control treatment is 33%.

These growths can be related to dramatic and continuing reductions in the total competitive index (CI) of non-tree species. The total post-treatment CI, in both treatments, is about half the pretreatment value, and has continued at that level for four growing seasons. In contrast, the total CI in the control is now about 10% higher than its pretreatment value.

The CI of all three target species in the control is about the same in 1987 as it was in 1983. In contrast, the CI of ninebark dropped to about 25% of its pretreatment value and has remained there for four growing seasons. The same trend is exhibited by snowberry and saskatoon with reductions to 5% and 30% respectively. There appears to be no difference in response between the two treatment rates, for all three species (Figures 3, 4 and 5).

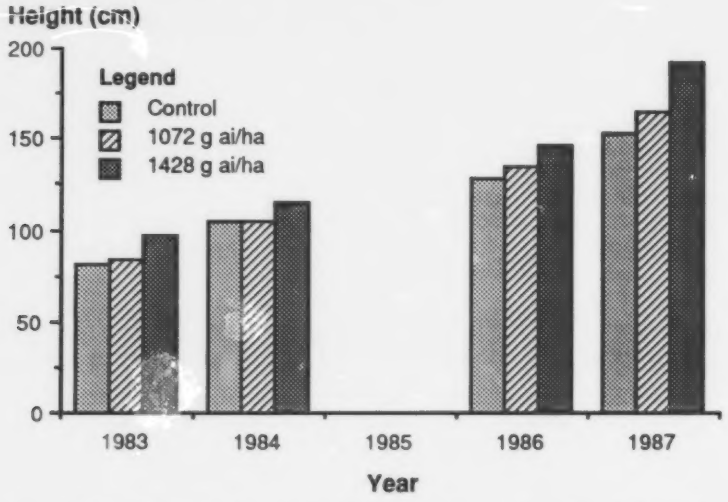

FIGURE 1. The effect of glyphosate applied at two rates on Douglas-fir height growth.

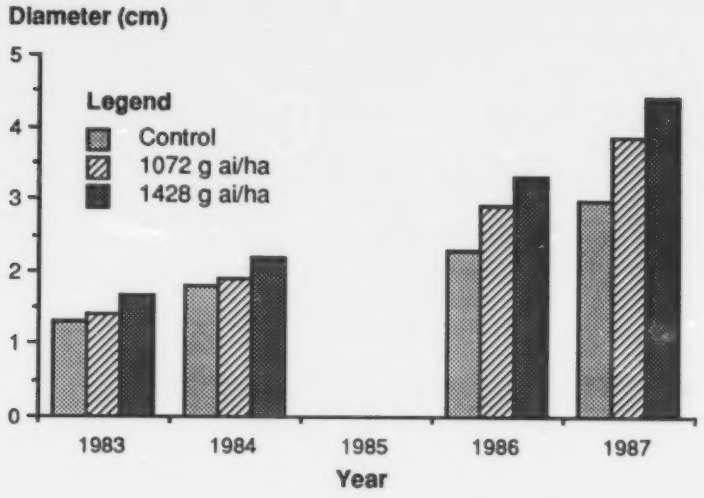

FIGURE 2. The effect of glyphosate applied at two rates on Douglas-fir diameter growth.

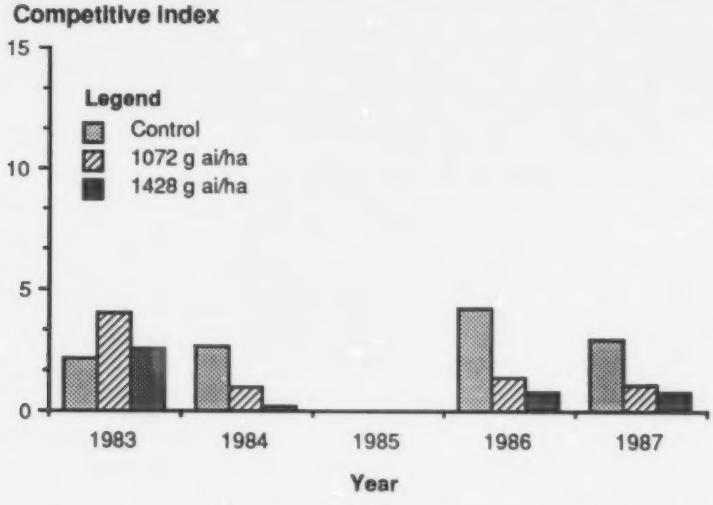

FIGURE 3. The effect of glyphosate applied at two rates on the competitive index of *Amelanchier alnifolia*.

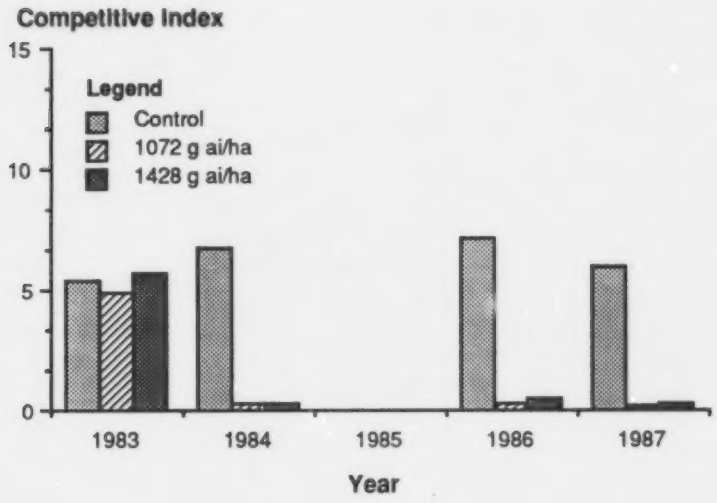

FIGURE 4. The effect of glyphosate applied at two rates on the competitive index of *Symphoricarpos albus*.

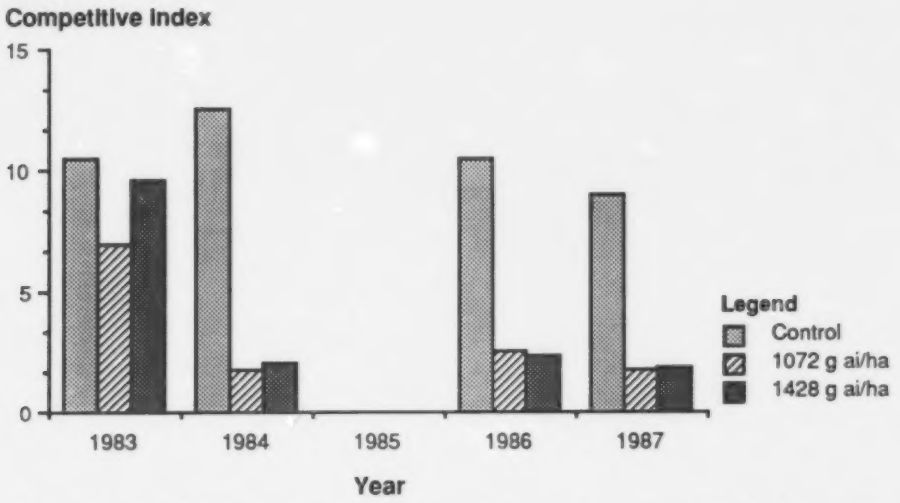

FIGURE 5. The effect of glyphosate applied at two rates on the competitive index of *Physocarpus malvaceus*.

CONCLUSIONS

Glyphosate applied in mid-August at rates of 1072 and 1428 g ai/ha was successful in controlling all three target species for at least four years. No difference in response due to the two rates tested is detectable. There was also a small response in both the height and diameter of eight-year-old Douglas-fir trees (average height 86 cm).

Although small, it is uncertain how long this growth effect will last. Comparison with untreated trees suggests that the difference in growth is increasing, but future assessments will be required to confirm this. That it occurred at all demonstrates, that on these sites, competition for resources (mainly for moisture) can be an important factor in the early performance of planted Douglas-fir. Earlier treatment may have had a greater effect on the growth and possibly also on the survival of these seedlings.

Ecology and Management of Broadleaved Species in the Oregon Coast Range

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Management of broadleaved woody species in the Oregon Coast Range is primarily for the purpose of reducing their impact on the establishment of conifer plantations. Sometimes, however, promoting the growth of selected broadleaved species for wood production, soil protection and enhancement, and fish and wildlife habitat improvement may be desirable. The management alternatives available vary by management objectives, site conditions, crop tree characteristics, species composition, economic considerations and political and legal constraints. Regardless of the objectives, the management alternative that provides an acceptable result at a low cost is always preferred. Choice of the best alternative from both ecological and economical points of view requires an understanding of the growth characteristics of the species and how they will be affected by the proposed treatment. This research is part of the COPE (Coastal Oregon Productivity Enhancement) program, a cooperative effort between Oregon State University and the Pacific Northwest Research Station, USDA Forest Service. We present two examples: development of salmonberry rhizomes and clones and establishment of common shrubs and hardwoods from seed.

Some of the most intense competition from broadleaved species occurs immediately after logging and other disturbances and originates from the sprouting of basal buds, and rhizome and root buds. These species, present before disturbance, survive from one rotation of conifers to the next. We have been studying the morphology and reproductive potential of the rhizome systems in salmonberry (*Rubus spectabilis*), one of the most severe competitors in coastal Oregon. The purpose of this work is to determine if the distribution of rhizomes in salmonberry is different among forest types and how the rhizome characteristics affect the regrowth response of salmonberry to harvesting and site preparation. Our results indicate that differences in the morphology of the rhizome system between mature red alder (*Alnus rubra*) and mature Douglas-fir (*Pseudotsuga menziesii*) stands may be large. In alder stands, for example, the average length of rhizome per clone is about 13 m; in Douglas-fir, about 2.5 m. The number of ramets is 1/m of rhizome in both stand types. The rhizome bud bank per clone is estimated to be about 600-700 in the alder stands and 100-200 in Douglas-fir stands. Our work, along with other COPE research, should provide a more quantitative basis for predicting salmonberry response and for developing alternatives for managing the response at critical stages of stand development.

The common broadleaved species in the Coast Range exhibit a variety of seed regeneration characteristics and potentials. We have studied the germination and survival of eight of these species: bigleaf maple (*Acer macrophyllum*), vine maple (*A. circinatum*), red alder, salal (*Gaultheria shallon*), thimbleberry (*R. parviflorus*), snowberry (*Symphoricarpos albus*), oceanspray (*Holodiscus discolor*), and blue elderberry (*Sambucus glauca*); and of Douglas-fir in a clearcut and in a mature Douglas-fir stand. The results from the first 2 years of the study and from some earlier work indicate that these species differ significantly in their biological characteristics and in their ability to become established at different stages of forest development and that management practices can alter the probability of establishment. Snowberry and vine maple, for example, germinate primarily during the second spring after sowing, whereas the other species germinate the first spring. Salal and oceanspray germinated well under both conditions but survived only in the stand. One species, blue elderberry, germinated only in the clearcut.

Our work and that of others indicates that management alternatives that take advantage of the ecological and biological characteristics and limitations of these species can be developed. Species such as bigleaf maple, salal, oceanspray, and vine maple become established from seed primarily in the

understory of young Douglas-fir stands. Thus, they might be controlled by regulating the seed source in and adjacent to such stands, by altering stand density, and by using light, prescribed fire, or by applying herbicides when plants are in the seedling stage. These are not the only variables to be considered when management alternatives are being developed. They are options to be used with other vegetation management alternatives to develop the most desirable practices for a particular set of circumstances. This information should improve our ability to predict the response of these species to harvesting and common management practices (herbicides, fire and manual cutting).

WORKSHOPS

COMPETITION AND RESPONSES: ENVIRONMENTAL FACTORS, SEEDLING PHYSIOLOGY, GROWTH ANALYSIS, AND POPULATION BIOLOGY

Environmental Factors Important in Vegetation Competition Studies

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The objective of this workshop was to provide a forum for discussing the measurement and interpretation of environmental data. The focus was on understanding the response of competing vegetation to environmental conditions and the impact of the vegetation on conifer seedlings. The workshop was held twice, with a total of 75 people attending. It was organized by Dr. Dave Spittlehouse, Research Branch, MoFL, Victoria. Dr. Stuart Childs of OSU, Corvallis, made a presentation which was followed by discussion with the participants and some comments by Dr. Andy Black of UBC, Vancouver.

The environment should be considered in terms of energy and water budgets. From this we are able to formulate conceptual models of the physiological response of the vegetation to its environment and the influence of the vegetation on the environment. This then leads to the determination of the response of the vegetation to manipulation at specific times of the year.

Environmental measurements are used to characterize the climate of an area and the microclimate of site treatments. The former can lead to a description of the long-term trend and is a basis for extrapolation, while the latter enables the comparison of treatments, process studies of the energy and water budgets and assessment of site variability. Measurement aids the verification of the conceptual models.

The minimum set of environmental measurements that should be collected at a site include air temperature, precipitation, soil moisture and soil temperature. Solar radiation can be calculated. Soil water status and soil temperature can be estimated once suitable models are calibrated and values of these variables at the start of any simulation are known. However, regular measurement of soil moisture is preferable. Site factors that must be measured include surface cover, soil texture, stone content, aspect, slope and elevation.

A variety of sensors and monitoring equipment are available to make the required measurements. Some environmental variables are more easily measured than others. However, the sampling frequency and intensity, and the level of technology, need not be onerous or sophisticated. Care must be taken in the location and maintenance of the monitoring equipment. Checking that sensors have maintained their calibration is an important activity as well as maintaining log sheets of site visits, problems and changes to sensors. Back-up measurements should be made where possible since they offer a check on the performance of the other sensors and can aid interpolation of data missing due to problems with the main monitoring system. For example, the back-up to a data logger monitoring system could include a storage rain gauge, max-min thermometer, thermograph and manual measurement of soil temperature with a portable probe. Data should be inspected as soon as possible, since this allows the rapid discovery of problems and minimizes data loss.

A variety of parameters derived from the measurements can be used in interpretations. These include the amount (extremes, means), quality (intensity and duration), distribution (spatial) and timing of the light regime, temperature and moisture regimes. Related factors such as soil heat capacity are also important.

Interpretation of the data in terms of limits, i.e. maximum and minimum values, is particularly appropriate for temperature and soil water potential. These limits can be related to the optimal, sub-optimal and lethal conditions for the seedling. For example, is a site too hot, too cold, too wet, too dry and/or too variable, and what are the operating windows? Manipulation of a site to modify one limiting factor can result in changes in both the upper and lower limits, and also changes in other limiting factors. Consequently, removing the detrimental effect of one limit on the seedling can result in the movement of the other limit into a non-optimal range. The duration of a particular condition is often as important as the intensity of this condition. Year-to-year variations in precipitation are often critical, and the distribution of precipitation through the growing season may be of greater importance than the total amount.

Methodologies to use environmental data in forest management are becoming available. The basic environmental data are of educational value, creating an awareness of the actual temperature and moisture regimes to which seedlings are exposed throughout the year. Light measurements can be used to determine the degree of competition experienced by seedlings. Interpretation of simulations using computer models can be done in terms of the probability of occurrence of certain conditions. Such information can aid the forester in making decisions by allowing an assessment of the risk that weather and site conditions impose on specific activities.

Physiology of Crop Trees: Response and Tolerance of Environmental Stress and Implications for Vegetation Management

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Stress is defined as a physical or chemical environment cue that causes seedlings to divert metabolic effort towards survival. Key features of stress include timing, intensity, duration and frequency. Imbalances and/or extremes in the environment of a seedling including temperatures, moisture, atmospheric gasses and particulates, physical/mechanical perturbation, light intensity and nutrition will stress seedlings. Operational practices that cause stress by influencing the seedling environment are presented in Table 1.

Seedlings respond to stress by:

1. shifting their metabolism to adjustment and repair;
2. accommodating energy concerns by efficient use of reserves and by avoiding energy overload; and
3. recovery.

TABLE 1. Operational practices that cause stress

Stress	Operational Situations
Frost	• Late fall freeze that kills stem, or roots. • Freeze storage without proper freezing or thawing technique. • Freezing during site storage on upper elevation sites.
Desiccation	• Root drying during lifting, temporary storage, and processing. • Drying due to vapor loss through holes in bags. • Condensation on inner surfaces of boxes in response to evaporative losses from heating during handling.
Flooding	• Transient waterlogging in container cavities during culture. • Exposure of roots to excess moisture in planting bags. • Prolonged root dipping.
Physical abuse	• Disease during culture. • Simple handling of seedlings when stress resistance is low. • Root damage during lifting or processing. • Jarring or shaking of bags/boxes during transit. • Slapping roots against an object to remove soil or ice prior to planting.
Heating	• Faulty cold storage facilities. • Transportation without refrigeration. • Local storage without refrigeration. • Transport to the site without proper insulation from radiation or heat sources.

The length of time required to recover and consequences of developmental setbacks are important considerations that have not been well characterized. Multiple stress events can have cumulative effects,

each event triggering a stress response that results in developmental delay and gradual vigor decline. The upshot of stress is loss of control.

Stress is expressed at the cellular level. Cell regulators that are sensitive to stress include pigments, hormones, membranes, DNA and enzymes (Figure 1). Pigments receive light energy cues that are used by the cell to create energy to do metabolic work, or to initiate an array of metabolic processes. Hormones receive and transfer different environmental cues to a genetic translator. DNA is the translator responsible for transforming cellular messages, derived from environmental cues via pigments, hormones and secondary messengers, into plant language. Enzymes (proteins) are the plants vocabulary which it uses to orchestrate cell function. Membranes compartmentalize the cell. Transport proteins, embedded in the membrane, coordinate flow of molecular traffic between compartments within the cell (organelles), and between cells. Surface-bound membrane proteins, facilitate production of energy for work (energy enzymes), or act as receptors for cellular messengers (hormones and secondary messengers) carrying environmental cues. These regulators work in coordination in the cell's signal-response pathway (Figure 2).

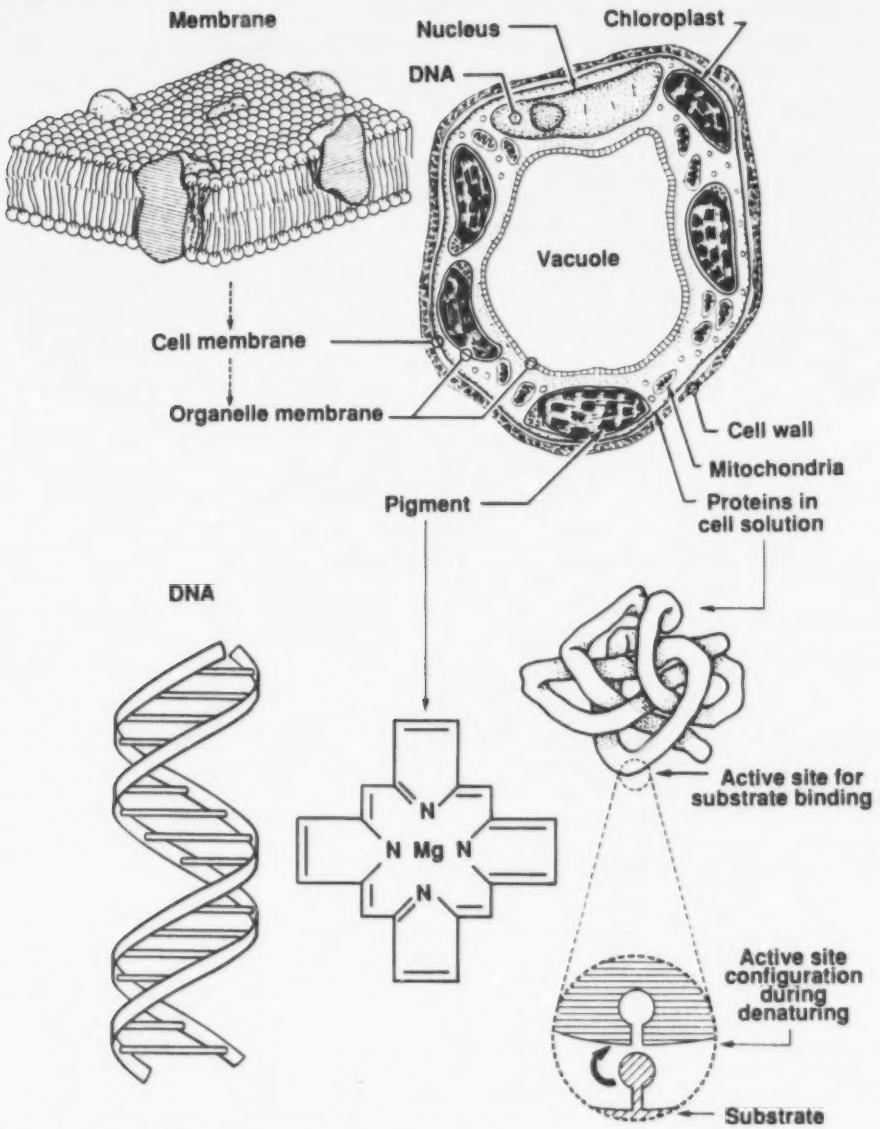

FIGURE 1 The cell and it's regulators.

The cumulative stresses encountered during lifting, processing, transport, and planting influence the seedlings ability to cope with site constraints (Table 2). Figure 3 demonstrates the adverse effects lifting and handling can have on volume growth, cold hardiness, and dormancy intensity when these practices are conducted outside the seedlings stress resistance window.

TABLE 2. Four days in the life of a seedling

Event	Elapsed time	Type of damage	Loss in survival potential (%)	
			Individual event	Cumulative loss
Lifting				
-Loss of roots and mycorrhiza.	2 min.	Physical	9	9
-Seedlings placed in tubs; exposed to sun and wind prior to pickup.	20 min.	Desiccation	7	16
Packing				
-Unloading seedlings in packing area; separation of seedlings produces root loss and loss of moisture.	2 min.	Physical and desiccation	6	22
-Exposure of seedlings on the grading belt.	30 sec.	Desiccation	2	24
-Rough handling in packing produces broken needles and crushed cambium.	30 sec.	Physical	5	29
Shipping				
-Bags are stacked four deep without spacers.	2 hours	Physical, overheating	7	36
Storage				
-Temporary storage does not have adequate air circulation.	2 days	Overheating	9	45
Planting				
-Exposure during planting.	20 min.	Desiccation	5	50

The subtle reality is that stress costs. Priorities shift from growth and development to adjustment and repair. Energy, substrates and functional and structural products are channeled towards survival mechanisms at the expense of normal growth and development. The severity of the situation is dependent on the timing, intensity, duration and frequency of individual stress events. Stress is cumulative and recovery to prestressed status is slow. The subtle nature of stress complicates assessment. Nursery managers and silviculturists lose control.

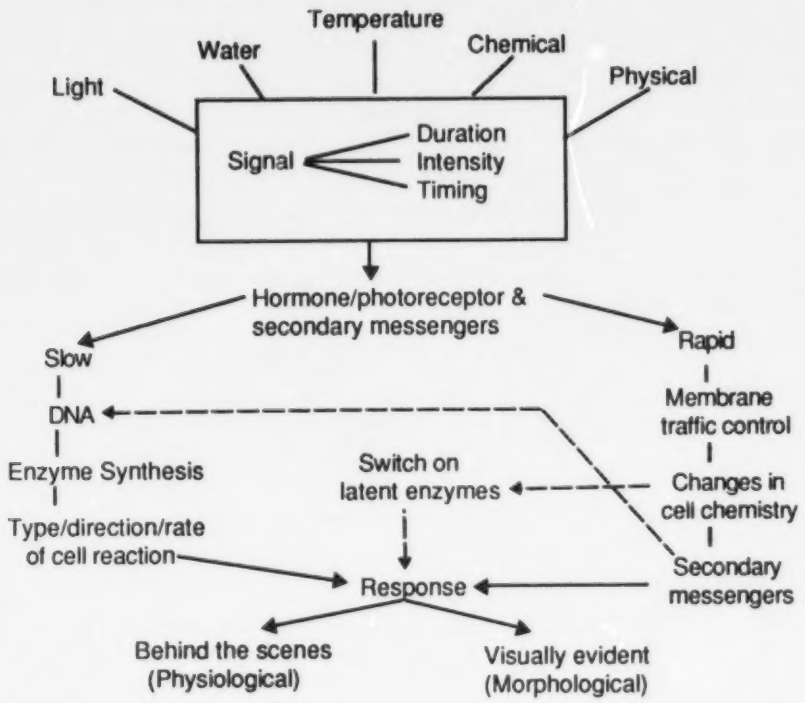

FIGURE 2. The signal-response pathway.

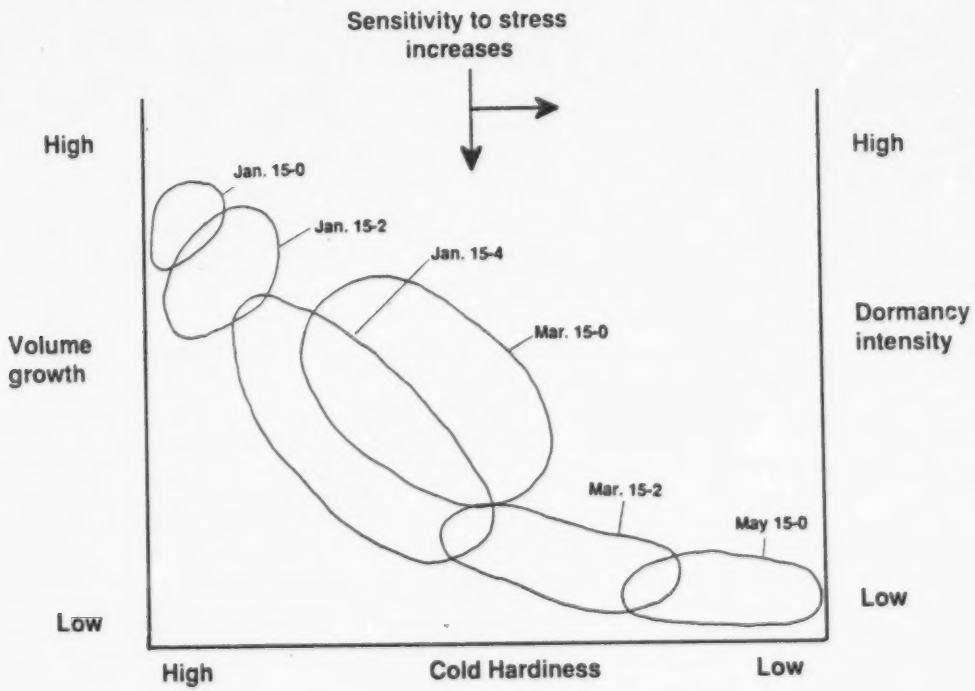

FIGURE 3. Sensitivity of seedlings to stress during the lift/store/plant phase.

Conifer Seedling Establishment on Reforestation Sites: Environmental Influences and Ecophysiological Responses

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Reforestation sites can create environmental extremes that cause physiological stresses in planted or natural seedlings. These stresses include:

1. greater incoming solar radiation;
2. greater air temperature extremes;
3. increased evaporative demand;
4. increased wind velocity;
5. greater soil temperature extremes;
6. excessive soil moisture in poorly drained soils; and
7. inadequate soil moisture in well drained poor sandy soils.

Diagnosing the cause of reduced seedling growth and/or mortality is a complex task. By examining the reforestation site microclimate characteristics in relation to seedling physiological responses, foresters will have a better understanding of what is needed for successful reforestation. Environmental characteristics and stresses during the planting, establishment and growth stages and the ecophysiological expressions of these stresses are outlined in Figure 1.

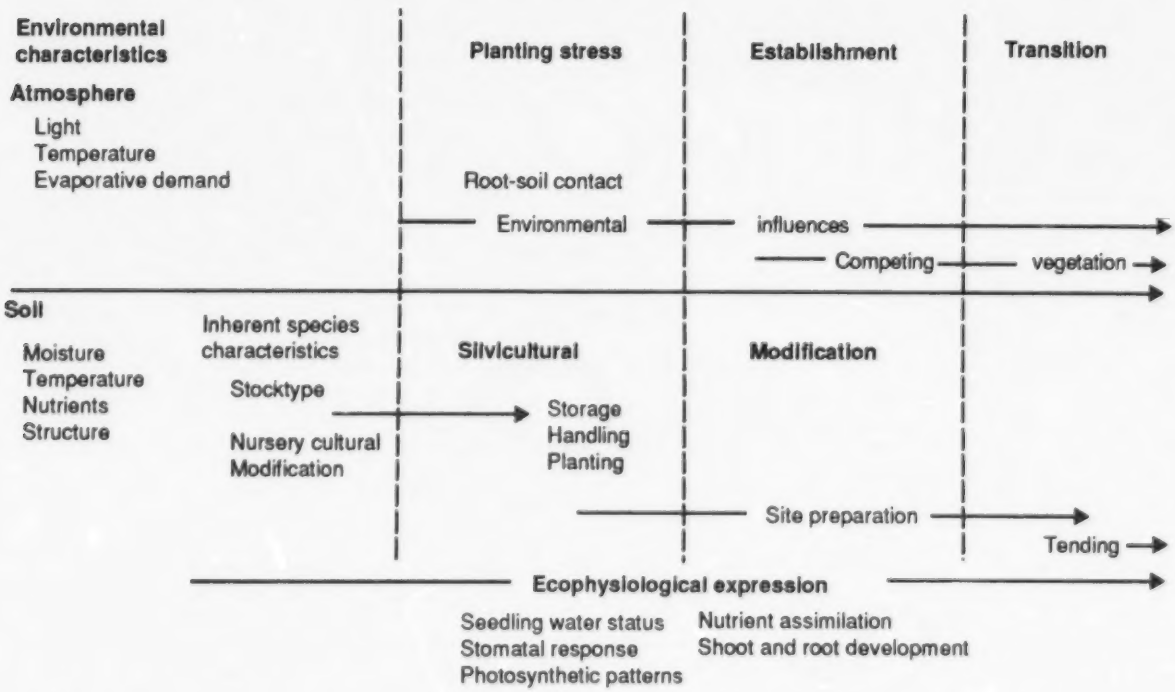

FIGURE 1. Environmental characteristics and ecophysiological expression during the planting establishment and growth phases.

Seedling water status and stomatal movement are physiological responses that change rapidly in field-planted seedlings. As a result, these physiological responses are considered to be an important means of monitoring the successful establishment of recently planted seedlings. Seedling water status and stomatal movement will respond to changes in the reforestation sites aboveground (i.e. light, temperature, evaporative demand) and belowground (i.e. temperature, moisture) characteristics.

Figure 2 outlines the magnitude of the reduction in seedling water potential required to influence various physiological and morphological processes in tree seedlings.

An understanding of how tree seedlings respond to site environmental conditions will lead to the identification of appropriate species-microsite conditions and improved seedling establishment.

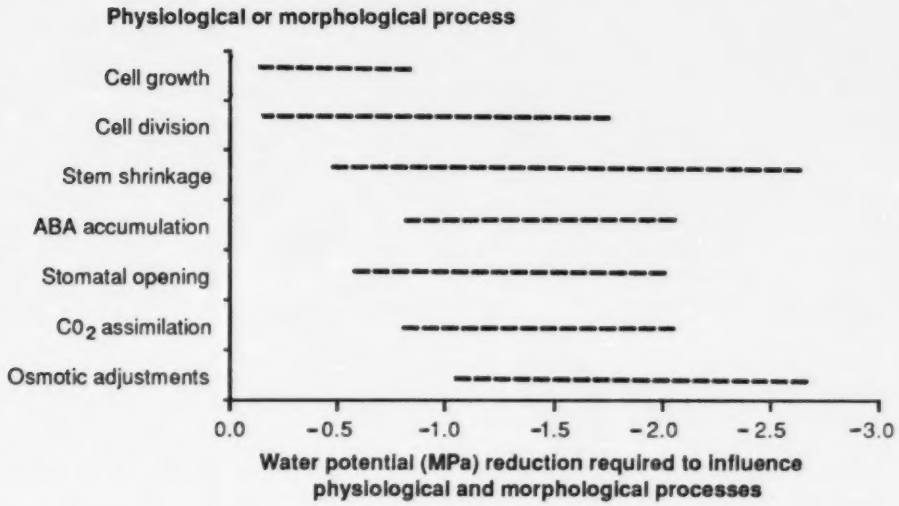

FIGURE 2. Water potential reduction required to influence physiological and morphological processes.

Plant Growth Analysis: Application to Vegetation Management Research

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GROWTH ANALYSIS APPLICATIONS IN FOREST RESEARCH

Introduction

Until recently, most research into production forestry has been empirical in nature, aimed at gaining quantitative estimates of tree and stand growth responses to site factors or silvicultural treatment. The reasons for this empirical approach included the difficulty and cost of more sophisticated research on plants the size of trees, and the long time periods involved in stand growth relative to agricultural crops. Recent research has increasingly concentrated on detailed physiological and environmental monitoring to supplement growth data (e.g. Draper *et al.* 1985; Grossnickle and Blake 1987; Flint and Childs 1987), but as has been found in botanical research (Warren Wilson *et al.* 1986), the link between mechanism and growth is often unclear. Growth analysis can provide a useful bridge between empirical and mechanistic research and there have recently appeared examples of this (Margolis and Waring 1986; Hobbs and Wearstler 1985).

A second major benefit of growth analysis is the provision of a size-independent measure of growth vigor. As most variation in growth increment is controlled by initial size (c.f. Alemdag 1978) the relative growth rate or, for trees, the relative production rate (Brand *et al.* 1987) can allow comparison of plants of different sizes on an equal basis. This feature is of particular importance in competition research where competition stress is usually inversely related to size. Examples of the use of growth analysis for this purpose are seen in Ford (1975), Radosevich (1984), and Brand (1986). A third use of growth analysis is the subdivision of response into yield components. An example of this is a Douglas-fir fertilization study carried out by Brix (1983), where he demonstrated the relative effects of increase in foliage efficiency and increase in foliage mass on growth responses over time.

Application of Growth Analysis to Competition Research

Much effort has been expended on defining the independent effect of competition on growth, as distinct from age or size related trends. The classical approach in forestry has involved the use of competition indices in stands (see Ford 1979), or young plantations (see Tappeiner and Wagner 1987). These indices generally describe either the amount of competitive shading on an individual tree basis, or describe total resource demand on a stand basis. Growth analysis may be particularly useful in conjunction with individual tree models. Indices calibrated with the absolute growth increment as the response variable include both size and competition effects, leading to erroneously high coefficients of determination. The smaller plants in a stand invariably have higher competition indices just because they are smaller, and as much ecological research has shown, small plants grow more slowly in absolute terms than large plants of the same age even when isolated and free from competition (Weiner 1985, Benjamin and Hardwick 1986).

Growth analysis can, to a large degree, remove the size effect and specifically quantify the competition effect on vigor. This is useful when looking at trees of different sizes in a stand, where growth is invariably related to size (Westoby 1982). Plots of relative growth rate versus size, for example, change from being negatively related to size where competition is low to being positively related to size in dense stands

(Perry 1985). Growth analysis can also be useful in the assessment of brush competition effects on young plantations. A small tree growing on a microsite surrounded by brush will grow more slowly than a larger open-grown tree because of both a size disadvantage and a reduced vigor or foliar efficiency. Studies that examine trees within a plantation and regress growth rate against individual tree competition indices will be biased and overestimate the impact of competition on growth.

Combining Growth Analysis with Environmental or Physiological Studies

Sophisticated analysis techniques have been developed that provide direct linkage with plant physiology or environmental conditions. These techniques, including nutrient use efficiency and light use efficiency, have had only limited use in forest research. Further, a new ecological theory with potential application in forest research uses growth analysis to quantify response to environmental stress (Hunt and Nicholls 1986). The model determines growth as a function of total stress (degree of difference from optimum), relative magnitude of above- and below-ground stress, and the plasticity of biomass allocation to adjust to differential levels of above- and below-ground stress, or attainment ratio.

Growth analysis can also be applied to the examination of plant response to specific environmental stresses, such as light, heat, moisture, and nutrition. For example, light stress due to competing vegetation can be broken into a partitioning coefficient, an efficiency coefficient, and an availability coefficient (c.f. Warren Wilson 1981).

Growth analysis is frequently used in combination with physiological studies. As a starting point, for example, growth analysis can be used to determine coarse treatment effects on biomass partitioning or foliar efficiency (Hawkins et al. 1985). More detailed physiological experiments can then be used to determine the causal agents of the changes. Growth analysis can also be used as a check in physiological experiments, where responses often change with ontogeny (indicated by changing growth rates). To ensure experiments are being conducted at similar stages of development, growth rates are calculated periodically on sample material. In some experiments, the relative growth rate is held constant and environmental conditions varied to study acclimation to stress (Waring *et al.* 1985).

MEASURING THE PRIMARY VALUES OF GROWTH ANALYSIS

The classical growth analysis equations require accurate estimation of the leaf surface area and biomass of sample plants. More sophisticated analysis will require other measures of biomass fractions, biochemical concentrations, or environmental conditions, but we will consider only the basic primary values here.

Biomass

The measurement of biomass can be carried out directly, by drying and weighing, or indirectly, by development of regression equations predicting biomass from more easily measured variables. The choice of technique will depend on the size of plants used, the number of samples required, and the desired or necessary level of accuracy. Use of regression requires particular caution, as equations based on allometric relationships that change with the conditions or variables under study can cause significant bias in results.

Leaf Area

There are two major methods available for directly estimating surface area: leaf area meters and volume displacement. The leaf area meters are based on video cameras or machines that integrate light interception by the leaf as it passes through a sensor field at known speed. These leaf area meters are rapid and accurate for relatively two-sided vegetation foliage (e.g. angiosperms). To accurately determine total surface area of *Picea* and *Pinus* requires a volume displacement method (Johnson 1984, Brand 1987). Leaf area is invariable calculated from subsampling each plant, then drying the subsamples and determining specific leaf area to correct the remaining foliage biomass to leaf area.

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Bud Bank, Seed Bank, Seed Rain and Forest Succession in the Coastal Western Hemlock Zone of Southwestern B.C.

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In Conard's (1984) problem analysis of forest vegetation management in B.C., she identified ten fields of research that she felt should receive high priority, among which were:

1. the autecology of competing vegetation;
2. the impact of different methods of site preparation on revegetation; and
3. the prediction of successional patterns.

These three topics are interrelated. Knowing the strategies of key species will help us understand and predict their response to disturbance, and perhaps could change the main focus of vegetation management from corrective to preventive measures.

The specific questions addressed here are:

1. what are the relative contributions of resprouting or residual vegetation, viable seeds stored in the soil, and dispersed seeds to the recruitment of species into scarified plots?; and
2. how do individual species respond to disturbance in terms of recovery and/or reinvasion?

Thirty 1 m^2 plots were scarified in March 1984 on each of two transmission line rights-of-way (ROWs) in coastal B.C.; the Cheekye Loop ROW 10 km north of Squamish, and the Malaspina ROW 30 km northwest of Sechelt. The vegetation adjacent to the scarified plots was assessed in the summer of 1984 in order to identify potentially invading species (the bud bank). Estimates of the reserve of viable seeds (samples collected in March 1984) stored in the forest floor and mineral soil (the seed bank) provided data on potential seedling recruitment after clearing as a function of clearing intensity. Data on seed dispersal or seed rain over a two year period, April 1984 - March 1986, provided information about the seasonal and spatial patterns of dispersal. Finally, observations of the recolonization of the scarified plots were made in August of 1984, 1985 and 1986 to determine the relative importance of the three strategies for key species.

Two plant associations dominated the ROWs: *Pteridium aquilinum-Gaultheria shallon* (PAGS) on xeric to sub-xeric, less disturbed sites, and *Rubus parviflorus-Alnus rubra* (RPAR) on sub-mesic to mesic, more disturbed sites. In general, the Cheekye Loop plots were predominantly of the PAGS association, while the Malaspina plots were of the RPAR association.

The dominant member of the seed bank at both sites, expressed both as seeds m^{-2} and as frequency of occurrence, was *Senecio sylvaticus*. *Alnus rubra* was notable by its low importance. *Gaultheria shallon* and *Anaphalis margaritacea* were more frequently found at the Cheekye Loop ROW. Seeds of *G. shallon* were found almost exclusively in the forest floor, and this layer was absent in most of the plots on the Malaspina ROW. Seeds of *Rubus* spp. were absent from the Malaspina scarified plot samples, but were present in samples taken at Malaspina for a study comparing seed banks of different ecosystems. In this other study, spores of *Pteridium aquilinum* were also found to be abundant in the forest floor.

The seed rain in the second year was greater than in the first. *Senecio sylvaticus* was absent from the seed rain in both years. The dominant member of the seed rain at both sites, in terms of frequency of occurrence, was *Alnus rubra*. *Gaultheria shallon*, *Anaphalis margaritacea*, and *Rubus* spp. were more frequently found at the Cheekye Loop ROW, although their occurrence was erratic.

Vegetative resprouting (from the bud bank) was an important mechanism for re-establishment by *Rubus ursinus*, *Pteridium aquilinum*, and *Gaultheria shallon*. Although *Senecio sylvaticus* and *G. shallon* were present and abundant in the seed bank - the latter only locally - this appears to have been an unimportant source of seedlings under the conditions experienced. *Anaphalis margaritacea* and *Rubus*

spp. seedlings were observed each year. Seedlings of *Alnus rubra* were extremely rare, although the failure of seedling establishment may reflect the dry ecosystems studied and/or the low summer rainfall experienced.

The work reported here suggests that removal of the forest floor may reduce competition from some species (*Gaultheria shallon, Pteridium aquilinum*) because the bud and seed banks of these species have been disturbed. At the same time, scarification may increase the risk of establishment of other competitors (*Alnus rubra*) by preparing an ideal seedbed. During the 3-year duration of this study, seeds of commercial conifers were rarely observed in either the seed rain or the seed bank. Although conifer regeneration is not desired on these transmission line rights-of-way, it would appear that reliance on natural regeneration in these parts of the Coastal Western Hemlock Zone should be discouraged.

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Reproductive Biology of Trees and Shrubs in Interior Alaska

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Forests of interior Alaska are the western-most extension of the boreal forests in North America. The major tree species on the more productive sites are white spruce (*Picea glauca*), paper birch (*Betula papyrifera*), quaking aspen (*Populus tremuloides*), and balsam poplar (*P. balsamifera*). Black spruce (*Picea mariana*) and tamarack (*Larix laricina*) predominate on less productive sites. The major tall shrub species are various willows (*Salix* sp.) and two alders (*Alnus incana* and *A. crispa*). The more productive forests occur on generally south-facing aspects and adjacent to major rivers. The work on which this discussion is based was done primarily on the Yukon-Tanana Upland and the adjacent Tanana River flood plain near Fairbanks, Alaska (lat. about 65°N.). Although I worked with both conifers and broadleaved woody species, this discussion focuses on the broadleaved species. Most of the research was conducted in areas that had been harvested, but the information also pertains to primary succession on flood plains and to secondary succession after wildfire.

The distribution, composition and rate of recovery of trees and shrubs depends primarily on the severity of disturbance, stand composition before harvest, and the quantity and timing of seed fall. Most of the species studied (willows, alder, paper birch, aspen and balsam poplar) have a high potential for vegetative reproduction from basal buds, roots or both, and are prolific seed producers. Recovery within a disturbed area is not usually uniform; that is, various-sized groups of single or multiple species are distributed over the area, and the composition and size of the groups are determined by the ability of the species to resprout or invade after a disturbance.

Vegetative reproduction has the potential for the most rapid recovery in terms of both height growth and area occupied. Of the named species, aspen has the greatest potential because of its tremendous capacity for producing root suckers. Relatively few aspen trees per hectare can result in 10 000 or more well-distributed suckers reaching heights of 2 m in 2 years and 7 to 10 m in 15 years. Balsam poplar has this capacity too, but it is not as prolific as aspen. Vegetative recovery in the other species is limited to resprouting from basal buds. The stand created by sprouting has the potential for the same stem distribution as that which occurred prior to harvesting, yet the potential is seldom realized because resprouting is affected by tree age, time of disturbance and damage to the stem base and root crown resulting from the disturbance. The potential for altering the distribution and vigor of the vegetative recovery process is great on sites where it is possible to select the best season for harvesting, harvesting methods and equipment for reducing or enhancing sprouting.

Seed regeneration depends on the availability of seed in adjacent areas (buried seed does not appear to be important for these species), the ability of the seed to germinate and the seedlings to become established on microsites created by logging and site preparation. Potential seed production for each species ranges from hundreds of thousands of seed for the smaller statured shrubs to millions of seeds per individual tree. The potential is not realized every year, yet total failures rarely occur for a given species. The potential for dispersal varies greatly among the species. Seeds of willow, aspen and balsam poplar travel for many kilometers and a large number of aspen seedlings were found on sites 1-2 km from the nearest seed source. Birch and alder are more limited in their dispersal ability. The percentage of the birch seed crop dispersed more than 100 m from the seed source is normally less than 5-10% of total seed production.

Seed longevity differs significantly among the Salicaceae species (willows, aspen and poplar) and birch and alder. Salicaceae species contain summer seed dispersers and fall seed dispersers. Seeds dispersed in the summer are very short-lived: those not germinating die within a few days to several weeks. Birch and alder are dispersed primarily in the fall and early winter and germinate the following spring. There are several reports of birch seed being stored in the forest floor for several years or more.

Managing the seed supply is possible, particularly for birch and alder. Depending on management objectives, these species can be removed from or maintained in the harvested or adjacent areas.

Managing the supply from Salicaceae species would most likely take advantage of the seed available by controlling seedbed conditions during dispersal.

Seedbed requirements are exacting. All species are favored by newly exposed or burned mineral soil surfaces. The Salicaceae species appear to be the most sensitive; I found few natural seedlings or had little success sowing these seeds in organic seedbeds. Seed to seedling ratios on freshly burned microsites varied from 20 to 60 seeds per 3-year-old seedling for birch and alder and from 400-1000 for 5 Salicaceae species in one study conducted on an upland site. Experience also suggests that seedbeds do not remain receptive for these species for more than one or two growing seasons. The implications are obvious for managing density of these species by altering surface conditions through burning or mechanical site preparation. A frequent concern is that any activity taken to encourage natural or artificial regeneration of white spruce, the most important commercial species, also encourages the invasion of the broadleaved species.

This information can be utilized in two ways for developing vegetation management prescriptions:

1. to develop prescriptions that either favor or deter establishment; and
2. to assist in interpreting and predicting the consequences of harvesting and site preparation methods on secondary succession, and for identifying sites that may require further treatment to achieve management objectives for timber, wildlife or soil management.

A Population Modeling Approach to Vegetation Management Research with Reference to *Rubus spectabilis* and *R. parviflorus*

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The objective of this paper is to discuss a population modeling approach to studying plant species (weeds) that require management on forest plantations. The modeling approach that we propose has two objectives: First, we want to develop basic knowledge on the population ecology of the weed species so that this knowledge can be used in assessing and developing control strategies; and second, we want to find the "Achilles heel" of each weed species by identifying biological processes which are most influential in regulating population growth.

Models have been developed for salmonberry (*Rubus spectabilis*) and thimbleberry (*Rubus parviflorus*) which simulate population growth in terms of ramet density. The models represent a population as a set of stage classes (seeds, buds, seedlings, sprouts, mature vegetative shoots and flowering shoots) and processes which occur between and within a stage class (transitions between classes, survival within classes and propagules and seed produced by each class). Sensitivity analysis was performed on the models to identify processes that are important in regulating population growth. Specific experiments were then designed to determine what mechanisms are involved in the important processes.

Initial sensitivity analysis on a generic model representing both salmonberry and thimbleberry indicated that bud elongation from sprouts and production of buds by vegetative and flowering shoots are important processes regulating population growth from basal buds. Three factors which influence the important processes involved with clonal population growth were identified for more focused study:

1. interference factors (intra- and inter-specific competition);
2. environmental factors (light, temperature and soil moisture); and
3. management factors (control methods).

Germination followed by seedling and seed survival were the most important processes regulating population growth from the seed.

Following validation, the models can be used to assess and develop management tactics that are aimed at the critical processes (Achilles heels), of these species. The modeling approach serves to organize existing information on a species, help identify information gaps, focus on important population growth regulating processes and provide a medium for assessing management strategies.

OTHER CONSIDERATIONS

A Technique for Measuring Light Interception Through Conifer Canopies

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In mesic forest ecosystems overstory canopy density is a critical parameter for predicting understory plant growth, biomass, diversity, fruit and flower production, seedling germination and seedling survival. A variety of techniques have been proposed to estimate overstory canopy density, but most of these have proven to be biased, low resolution, or too time consuming for practical field application. For this study a technique was developed which allows for rapid assessment of the opaqueness or density of overstory canopies for comparisons both between sites and within sites.

METHODS

Vegetation on the study site was dominated by *Tsuga heterophylla* and *Picea sitchensis* in the overstory, and *Vaccinium ovalifolium, V. alaskaense*, and *Cornus canadensis* in the understory. The forest consisted of a mosaic of old growth patches interspersed with recent to centuries-old canopy gaps caused by windstorms or disease. Five hectares of the forest was logged 45 years ago and consisted of a dense, nearly continuous coniferous canopy 25 m high with little understory vegetation. Site index of the second growth stand was 25m/50yr. Basal area averaged 53 m^2/ha for both age classes. Study sites were located near Juneau, Alaska.

Paired Licor, Inc. spherical quantum radiometers (LI-173), with a spectral sensitivity of 400-700 nm (PAR) and a 360 degree angle of acceptance were used for all measurements. For instantaneous readings under the forest canopy the first radiometer was connected to an ohm meter for direct readout. This radiometer was moved to each of 100-150 points beneath the forest canopy to make measurements at hourly intervals throughout the day on sunny days and within 1 hour of solar noon on overcast days. To measure open sky radiation, the second radiometer was used with a datalogging system so that variation in radiation could be monitored continuously and with high resolution (5-30 second averages). The two sets of observations were then merged together for the calculation of percent light transmission. Results were also validated with 7 radiometers simultaneously interfaced to two datalogger systems to track variation in percent radiation transmission over a one-week period.

RESULTS

A wide range of light values were estimated within each of the two forest age classes, but in general the old growth stand had 3-5 times the proportion of light as the younger stand. The largest canopy gaps generally had 4-6 percent light transmission, whereas the densest portions of the second growth stand had 0.7 to 0.9 percent light transmission on a cloudy day. The same sites were estimated as having 85-100% canopy cover, with no significant difference between them using a spherical densitometer.

The two stands had dramatically different vegetation generally consistent with the measured pattern in light transmission. For example the plots with greater than 4% light were dominated by shrubs, the plots with greater than 2% were dominated by shade tolerant herbs and ferns and those with less than 2% light were dominated by bryophytes. It would have been difficult to predict this pattern in vegetation structure with ocular canopy cover estimates or photo-derived estimates of light transmission since complete canopy cover occurred at several points in both second growth and old growth forests but with significantly different light levels and vegetation structure.

On cloudless days, percent light transmission was highly variable over the day. The greatest site differences occurred at intermediate solar azimuths. The old growth site on a gentle slope (<20%) had

significantly more light transmission throughout most of the day than the old growth site on a flat bench ($p > 0.95$).

Estimates of percent radiation transmission on overcast days made between 9:00 and 15:00 solar time were generally within one percent of one another. Light transmission was similar on sunny days and cloudy days for all sites when comparing data collected within two hours of solar noon. Little variation was detected in percent light transmission during the bulk of the growing season, but significantly less transmission occurred during the first week in September than from July to mid-August ($p > 0.95$).

In climates with frequently overcast skies direct radiation measurements with a light meter may prove to be nearly as time efficient as canopy cover techniques but provide greater sensitivity in distinguishing high levels of canopy density. Unless an extremely patchy canopy is being measured with a large portion of sidelighting, it should be possible to characterize light penetration through most forest canopies by simply making 2-5 measurements at each sample point on an overcast day within 2 hours of solar noon within two months of the summer solstice. The reduced diurnal variation of radiation on overcast days also makes practical measurements of light attenuation with respect to height under forest canopies.

In many instances the complexity of characterizing spatial and geometric variation in overstory canopy structure directly may be far more difficult and error prone than simply using the radiometer as the integrator of these structural features. This radiation measurement technique has been successfully applied to a wide range of vegetation research problems in Alaska including evaluating effects of thinning, comparing ecosystem types, predicting plant succession and in making wildlife habitat assessments.

Integrated Use of Field Survey Data: A Pilot System

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INTRODUCTION

As the area of plantation forest expands, foresters must apply increasingly extensive management systems to maintain a given level of information on a particular opening. Data collected by field surveys is used for only a single purpose (e.g. determine stocking, survival or regeneration performance), or with limited secondary analysis. Single purpose surveys, designed to answer a particular question, are inefficient and should be replaced by more integrated systems of data collection and use. At the free-growing assessment stage, for example, the data collected could be used for assessing stocking and stocking pattern, developing a brush control prescription, producing field maps of stand condition, priorizing diverse areas for allocation of treatment programs and as input to early stand projection models. A pilot system, developed at the Petawawa National Forestry Institute, demonstrates this type of integrated information use.

SYSTEM COMPONENTS

The system uses a field survey with the Husky Hunter portable electronic notebook to gather data on plot locations, tree height growth, stocking, and competing vegetation. Data from the survey is written in a format for a FORTRAN summary program which projects free-growing status for each tree, summarizes total and free-growing stocking, competing vegetation characteristics and height growth trends. Another output file is created based on the bearings and distances used in the survey to create (x, y) coordinates for each plot. This file is used to calculate the spatial autocorrelation (I-statistic) in total and free-growing stocking. The plot locations, total and free growing stocking, and I-statistics are then used to produce a stand-level representation of the survey data with a GIS. This final map could be used for planning field operations such as brush control or fill planting.

Prediction of the Rotation-length Consequences of Alternative Vegetation Management Strategies for Timber Yields, the Stand-level Economic Performance of Management, Soil Fertility and Site Productivity using the Ecosystem-level Forest Management Model FORCYTE-11

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Negative interactions between crop trees and non-crop vegetation can result in both delayed (or failed) regeneration and reduced yields at the end of the rotation. Short-term (5-10 yr.) research projects are able to give us empirical evidence of the effects of these negative impacts over the period of study, but it may be difficult to predict from these projects the rotation-length consequences of the management or the lack of management of these impacts. Although it is very important to understand and be able to predict the short-term consequences, ultimately, it is the rotation-length consequences of vegetation management decisions that are of the greatest concern to the forest manager.

Non-crop vegetation may have beneficial effects as well as negative effects on crop trees. Sometimes the effects may be positive initially and then become negative, and the reverse can also be true.

The complexity of the interactions between crop and non-crop plants, the lack of financial and manpower resources to study them on all the sites, on which they are a problem, and the lack of time to obtain empirical evidence concerning the rotation-length consequences of the management of the interactions suggests the need for computer simulation modelling. Such modelling must be conducted at the ecosystem level if the complex and temporally-variable interactions between different plant life forms and the soil resources of the site are to be accounted for.

The purely process simulation approach has not yet produced ecosystem-level vegetation management simulations that are suitable as practical decision support tools for forestry. The historical bioassay (i.e. mensurational or regression-based) type of model is excellent where one has the empirical data necessary to calibrate the model for all site and treatment combinations of interest over one to several tree crop rotations. Where such data are not available, the hybrid simulation approach (combination of an historical bioassay approach with some simulation of processes) appears to be the best available alternative.

FORCYTE-11 is an example of such an ecosystem-level hybrid simulation model. It can simulate the competition between crop and non-crop vegetation for soil nutrients and for light (i.e. it simulates shading effects), and the effects of soil nutrient availability (i.e. soil fertility) on plant growth. It can predict biomass production, yield, stand-level economics of silviculture and soil fertility. It can examine the probable short, medium and long-term (up to several rotations) effects of various alternative vegetation management strategies (including manual, mechanical, chemical, biological and fire-related treatments) for site preparation, competition control and stand release.

FORCYTE-11 can be used on a 386-generation microcomputer, or on any IBM-compatible microcomputer equipped with a 2 MB 32-bit co-processor. The "benchmark" version of FORCYTE-11 will be demonstrated in workshops, and will be available for purchase, in the fall of 1988. Anyone interested in attending one of these workshop/demonstrations, in organizing a workshop/demonstration in their area, or simply finding out more about the model, is invited to write to the senior author.